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1800

USEFUL INFORMATION

FOR

RAILWAY MEN.

COMPILED FOR

THE RAMAPO WHEEL AND FOUNDRY CO.,

BY

W. G. HAMILTON, ENGINEER.

SECOND EDITION, REVISED AND ENLARGED.

1869
CITY OF WASHINGTON

New York:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY ST. AND 27 WARREN ST.

1869

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W. G. HAMILTON,

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PREFACE.

The first edition of the following pages, mainly compiled from the works of Clark, Colburn, Bourne, Haswell, Hurst, Molesworth, Nystrom, Percy, Scribner, Templeton, Ure, Price Williams, American Railroad Journal, Engineering, and Railway Times, were printed for private distribution.

To meet the applications from railway men, a new edition, revised and much enlarged, is now offered for sale.

It is hoped they may prove of service to the railway community, and promote the interests of the Ramapo Wheel and Foundry Co.

PREFACE.

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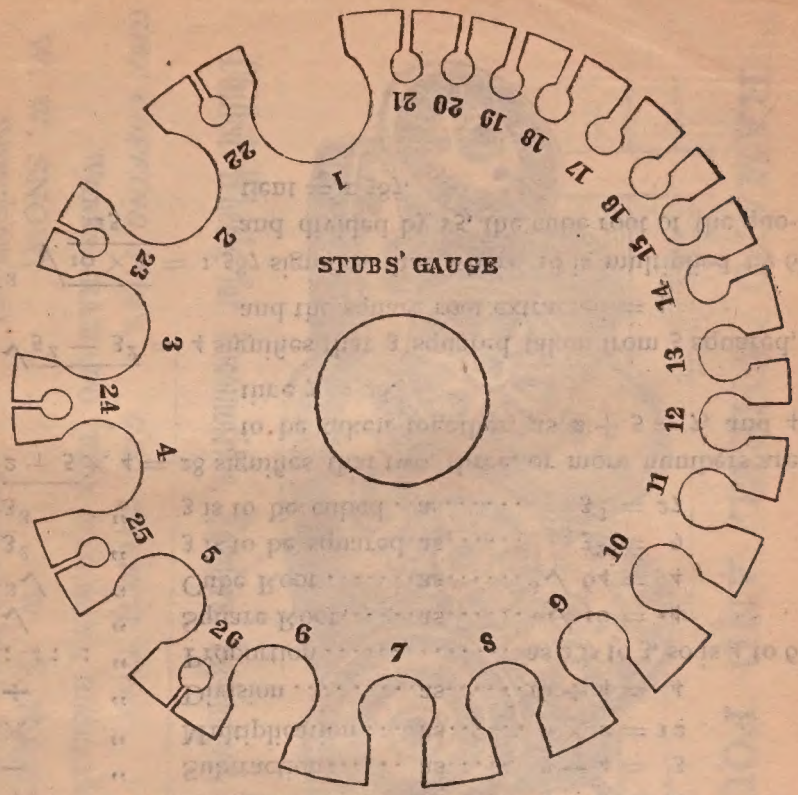
RAMAPO WHEEL AND FOUNDRY CO.



Birmingham Wire Gauge, Compared with Inches.

B. W. G.	= ins.	B. W. G.	= ins.	B. W. G.	= ins.	B. W. G.	= ins.
No. 1	= .31	No. 10	= .137	No. 19	= .042	No. 28	= .014
2	.28	11	.125	20	.035	29	.013
3	.26	12	.109	21	.032	30	.012
4	.24	13	.095	22	.028	31	.01
5	.22	14	.083	23	.025	32	.009
6	.2	15	.072	24	.022	33	.008
7	.187	16	.065	25	.02	34	.007
8	.166	17	.056	26	.018	35	.005
9	.158	18	.049	27	.016	36	.004

No. 1 W. G. = . . .	$\frac{5}{16}$ in	No. 11 W. G = . .	$\frac{1}{8}$ in.
4 " . .	$\frac{1}{4}$ in	16 " . .	$\frac{1}{16}$ in.
7 " . .	$\frac{3}{16}$ in.	22 " . .	$\frac{1}{32}$ in.

SIGNIFICATION OF SIGNS USED IN CALCULATIONS.

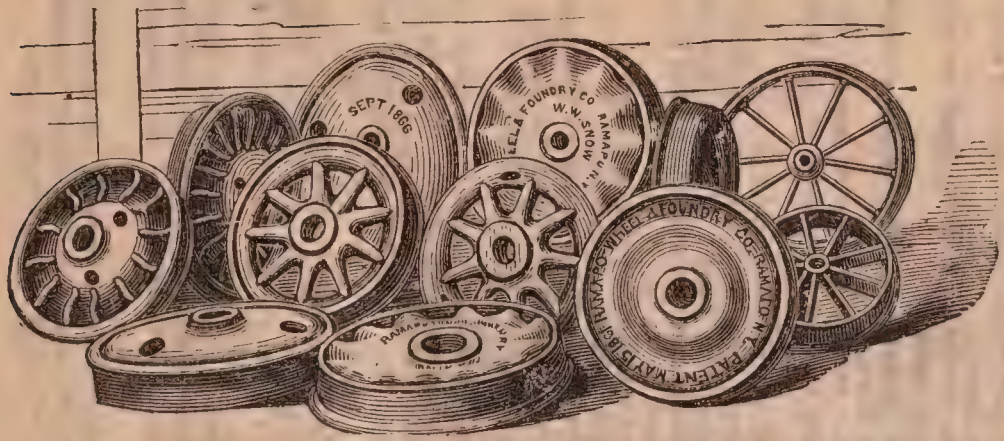
$=$	signifies	Equality.....as.....	3 added to $2 = 5$
$+$	"	Addition .....as.....	$4 + 2 = 6$
$-$	"	Subtraction..... as.....	$7 - 4 = 3$
$\times$	"	Multiplication ....as.....	$6 \times 2 = 12$
$\div$	"	Division .....as.....	$16 \div 4 = 4$
$: :: :$	"	Proportion .....as 2 is to 3, so is 4 to 6	
$\sqrt{}$	"	Square Root.....as.....	$\sqrt{16} = 4$
$\sqrt[3]{}$	"	Cube Root .....as.....	$\sqrt[3]{64} = 4$
3^2	"	3 is to be squared.as.....	$3^2 = 9$
3^3	"	3 is to be cubed ..as.....	$3^3 = 27$

$\overline{2 + 5} \times 4 = 28$ signifies that two, three, or more numbers are to be taken together, as $2 + 5 = 7$, and 4 time $7 = 28$.

$\sqrt{5^2 - 3^2} = 4$ signifies that 3 squared taken from 5 squared, and the square root extracted $= 4$.

$\sqrt[3]{\frac{10 \times 6}{15}} = 1.587$ signifies that where 10 is multiplied by 6 and divided by 15, the cube root of the quotient $= 1.587$.

RAMAPO WHEEL AND FOUNDRY CO.



Chilled Wheels for Locomotives, Tenders, Passenger, and Freight Cars.

GEO. COFFING, Pres't. *GEO. CHURCH, Treas.* *C. T. PIERSON, Sec.*

WORKS—RAMAPO (ERIE RAILWAY), ROCKLAND CO., N. Y.

W. W. SNOW,
Superintendent.

W. G. HAMILTON,
Agent and Eng'r, 24 Broadway, New York.

Richmond Iron.

RATES OF POSTAGE.

On all Letters to any part of the United States, 3 cents for each ½ ounce or fraction thereof.

Drop or Local Letters, 2 cents for each ½ ounce or fraction thereof; no carrier's fee for delivery.

Printed Books, in one package, to one address, 4 cents for each 4 ounces or fraction thereof.

Circulars, unsealed, not exceeding three in number, to one address, 2 cents; the same rate for every three or less number additional.

On all transient printed matter (books and circulars excepted), and on all Seeds, Cuttings, &c., Pamphlets, Book MSS. and Proof-sheets, Maps, Engravings, Blanks, Patterns, Envelopes, and Photographs, one package, to one address, 2 cents for each 4 ounces or fraction thereof.

On all matter not above specified, same rate as letters.

All transient matter must be prepaid by stamps.

No package will be forwarded which weighs over four pounds, except books published or circulated by order of Congress.

Valuable Letters may be registered on the payment of a registration fee of 20 cents.

Absolute safety in sending money by mail is secured by obtaining a Money Order, on any Money Order Office, for which the fees are: On sums less than $1 and not over $10, 10 cents; over $10 and not exceeding $20, 15 cents; over $20 and not exceeding $30, 20 cents.

On Letters to Canada and other British North American Provinces, when not over 3,000 miles, 10 cents for each ½ ounce; when over 3,000 miles, 15 cents. Prepayment optional—whole or none to be paid.

To Great Britain or Ireland, 12 cents. Prepayment optional.

To France, 15 cents each ¼ ounce. Prepayment optional.

To the German States, by Prussian closed mail, prepaid, 28 cents; unpaid, 30 cents.

Letters to other Foreign Countries vary in rate according to the route by which they are sent, and the proper information can be obtained of any Postmaster in the United States.

PITTSBURGH

CAST-STEEL SPRING COMPANY,

MANUFACTURERS OF

EXTRA TEMPERED LIGHT ELLIPTIC

CAST-STEEL SPRINGS,

FOR

RAILROAD CARS AND LOCOMOTIVES,

FROM BEST CAST-STEEL.

A. FRENCH, Superintendent.

OFFICE AND WORKS,

Corner of Liberty and Twenty-first Streets,

PITTSBURGH, PA.

Map to accompany
USEFUL INFORMATION
FOR RAILROAD MEN
Compiled for
The Ramapo Wheel & Foundry Co.
by W. G. Hamilton Engineer.
UNITED STATES
MEXICO
GULF OF MEXICO
ATLANTIC OCEAN
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEBRASKA
KANSAS
DAKOTA
MINNESOTA
IOWA
MISSOURI
ARKANSAS
TEXAS
INDIAN TERRITORY
ILLINOIS
WISCONSIN
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
VERMONT
MAINE
QUEBEC
ONTARIO
NOVA SCOTIA
NEW BRUNSWICK
BAHAMA IS.
Salt L.
Denver
Pikes Peak
Santa Fe
Prescott
Tucson
Chihuahua
Monterey
San Francisco
Sacramento
Portland
Olympia
Helena
Cheyenne
Omaha City
Yankton
St. Paul
Chicago
Detroit
Toronto
Montreal
Quebec
Boston
New York
Philadelphia
Washington
Richmond
Raleigh
Charleston
Savannah
Jacksonville
Tallahassee
Mobile
New Orleans
Galveston
Austin
Dallas
Little Rock
Memphis
Nashville
Louisville
St. Louis
Cairo
Cincinnati
Indianapolis
Columbus
Lansing
Madison
Springfield
Jefferson City
Topeka
Leavenworth
Des Moines
Dubuque
Galena
Green Bay
Milwaukee
Superior
Duluth
Sault Ste. Marie
Mackinaw
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Lake Michigan
Lake Superior
Cape Canaveral
Tampa
Key West
Havana
Bahama I.
Abaco
Andros I.
Cuba

MAP SHOWING LOCATION OF RAMAPO, N. Y., AND RICHMOND, MASS.

Richmond Iron

RAMAPO WORKS.

The village of Ramapo, on the Ramapo River, Rockland county, New York, the location of the Ramapo Wheel and Foundry Company, and of the Ramapo Car Works—population 700—is on the line of the Erie Railway, distant from New York city 33 miles.

It was established by J. G. Pierson & Brothers in 1790—its water power having been employed in the manufacture of nails, iron, steel, cotton goods, and wood screws.

The first cut nails made in this country were made here, as also the invention of machinery for making wood screws, which has since been transferred to Providence, R. I., and has resulted in the extensive concern of the American Screw Company.

The rapid communication with New York, water power, and wild mountain scenery, render this place attractive as a residence, and to the manufacturer few places possess greater advantages.

To Calculate Value per Ton of 2,000 Pounds at from 1-16 of a Cent per Pound to 12⅞ Cents per Pound.

	$		$		$		$		$		$		$
1-16	1.25	1⅞	37 50	3¾	75.00	5⅝	112.50	7½	150.00	9⅜	187.50	11¼	225.00
⅛	2.50	2	40.00	3⅞	77.50	5¾	115.00	7⅝	152.50	9½	190.00	11⅜	227.50
¼	5 00	2⅛	42.50	4	80.00	5⅞	117.50	7¾	155.00	9⅝	192.50	11½	230.00
⅜	7.50	2¼	45.00	4⅛	82.50	6	120.00	7⅞	157.50	9¾	195.00	11⅝	232.50
½	10.00	2⅜	47.50	4¼	85.00	6⅛	122.50	8	160.00	9⅞	197.50	11¾	235.00
⅝	12.50	2½	50.00	4⅜	87.50	6¼	125.00	8⅛	162.50	10	200.00	11⅞	237.50
¾	15.50	2⅝	52.50	4½	90.00	6⅜	127.50	8¼	165.00	10⅛	202.50	12	240.00
⅞	17.50	2¾	55.00	4⅝	92.50	6½	130.00	8⅜	167.50	10¼	205.00	12⅛	242.50
1	20.00	2⅞	57.50	4¾	95.00	6⅝	132.50	8½	170.00	10⅜	207.50	12¼	245.00
1⅛	22.50	3	60.00	4⅞	97.50	6¾	135.00	8⅝	172.50	10½	210.00	12⅜	247.50
1¼	25.00	3⅛	62.50	5	100.00	6⅞	137.50	8¾	175.00	10⅝	212.50	12½	250.00
1⅜	27.50	3¼	65.00	5⅛	102.50	7	140.00	8⅞	177.50	10¾	215.00	12⅝	252.50
1½	30.00	3⅜	67.50	5¼	105.00	7⅛	142.50	9	180.00	10⅞	217.50	12¾	255.00
1⅝	32.50	3½	70.00	5⅜	107.50	7¼	145.00	9⅛	182.50	11	220.00	12⅞	257.50
1¾	35.00	3⅝	72.50	5½	110.00	7⅜	147.50	9¼	185.00	11⅛	222.50		

Notable Events.

B. C. 4004—Creation of the world. (According to Julius Africanus, Sept. 1, 5508; Samaritan Pentateuch, 4700; Septuagint, 5872; Josephus, 4658; Talmudists, 5344; Scaliger, 3950; Petarius, 3984; Hales, 5411.)

" 2348—Deluge. (According to Hales, 3154.)

" 2090—First Egpytian Pyramid.

B. C. 1111—Mariner's compass discovered.

" 605—Geometry, maps, etc., introduced.

" 341—Coal first noticed.

" 289—First sun-dial.

" 219—Surveying first introduced.

" 200—Expansive force of steam first spoken of by Hero of Alexandria.

" 155—Time first measured by water.

To Calculate Value per Ton of 2,240 Pounds at from 1-16 of a Cent per Pound to 12⅞ Cents per Pound.

	$		$		$		$		$		$		$
1-16	1.40	1⅞	42.00	3¾	84.00	5⅝	126.00	7½	168.00	9⅜	210.00	11¼	252.00
⅛	2.80	2	44.80	3⅞	86.80	5¾	128.80	7⅝	170.80	9½	212.80	11⅜	254.80
¼	5.60	2⅛	47.60	4	89.60	5⅞	131.60	7¾	173.60	9⅝	215.60	11½	257.60
⅜	8.40	2¼	50.40	4⅛	92.40	6	134.40	7⅞	176.40	9¾	218.40	11⅝	260.40
½	11.20	2⅜	53.20	4¼	95.20	6⅛	137.20	8	179.20	9⅞	221.20	11¾	263.20
⅝	14.00	2½	56.00	4⅜	98.00	6¼	140.00	8⅛	182.00	10	224.00	11⅞	266.00
¾	16.80	2⅝	58.80	4½	100.80	6⅜	142.80	8¼	184.80	10⅛	226.80	12	268.80
⅞	19.60	2¾	61.60	4⅝	103.60	6½	145.60	8⅜	187.60	10¼	229.60	12⅛	271.60
1	22.40	2⅞	64.40	4¾	106.40	6⅝	148.40	8½	190.40	10⅜	232.40	12¼	274.40
1⅛	25.20	3	67.20	4⅞	109.20	6¾	151.20	8⅝	193.20	10½	235.20	12⅜	277.20
1¼	28.00	3⅛	70.00	5	112.00	6⅞	154.00	8¾	196.00	10⅝	238.00	12½	280.00
1⅜	30.80	3¼	72.80	5⅛	114.80	7	156.80	8⅞	198.80	10¾	240.80	12⅝	282.80
1½	33.60	3⅜	75.60	5¼	117.60	7⅛	159.60	9	201.60	10⅞	243.60	12¾	285.60
1⅝	36.40	3½	78.40	5⅜	120.40	7¼	162.40	9⅛	204.40	11	246.40	12⅞	288.40
1¾	39.20	3⅝	81.20	5½	123.20	7⅜	165.20	9¼	207.20	11⅛	249.20		

Notable Events.

A. D. 37—Christ crucified.
" 214—Grist-mills introduced.
" 667—G ass discovered.
" 991—Arabic numerals introduced.
" 1180—Mariner's compass introduced into Europe.
" 1383—Cannon introduced.
" 1492—America discovered.
A. D. 1627—Barometer and thermometer invented.
" 1650—Coal railways used in England.
" 1747—Discovery of the Leyden jar.
" 1768-69—Anthracite coal first used.
" 1797—Boat propelled by steam by John Fitch.
" 1800—Voltaic battery discovered.

FRONT OF WORKS OF RAMAPO WHEEL AND FOUNDRY CO.

The Ramapo Wheel and Foundry Co.,

MANUFACTURERS OF

SUPERIOR CAR WHEELS,

AND

CASTINGS FOR RAILWAY PURPOSES.

—o—

Works at RAMAPO, ROCKLAND CO., N. Y., on the line of the Erie Railway, distant from NEW YORK CITY thirty-three miles, and from the Hudson River, at PIERMONT, twenty miles.

The works of this company, having a capacity for the manufacture of one hundred and twenty wheels per day, and extensive facilities for making castings for Railways, are prepared to fill orders; and, with tools of the most recent improvement, to fit up Wheels and Axles, or bore Wheels, to standard guages, for LOCOMOTIVES, PASSENGER, FREIGHT, and COAL TRAFFIC.

The advantages of this foundry are derived from its connection with the manufacturers of two of the most noted irons produced in the country (probably in the world), for castings of a superior quality. These irons are from the celebrated Hematite ores of the RICHMOND IRON WORKS, in BERKSHIRE COUNTY, MASSACHUSETTS, and SALISBURY MINES, LITCHFIELD COUNTY, CONNECTICUT.

Ramapo Wheel and Foundry Co.

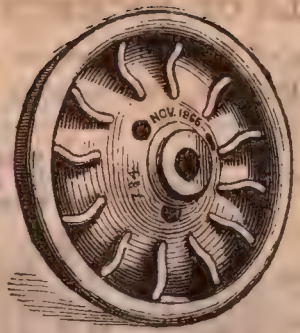
The reputation of these irons, of so long standing (having been wrought nearly one hundred and twenty years in every department of mechanism where a superior combination of qualities are necessary), is conclusive evidence of their adaptation to the uses to which they have been, and are, constantly applied.

The great responsibility resting upon Railway Corporations necessitates the selection and procuring of WHEELS made of an iron that will do the best service, and has done much to enforce upon foundrymen the importance of greater care and vigilance, thus compelling the makers of iron to a more thorough, rigid, and uniform system of manufacture than is found in any other foundry work, except it be for ordnance purposes.

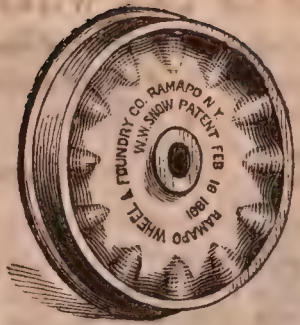
We believe that, with these combinations in the iron, we are producing wheels possessing all the qualities for service that can be united in their construction, and, in offering them to Railways, are sanguine that a trial will prove them to be unsurpassed in this or any other country.

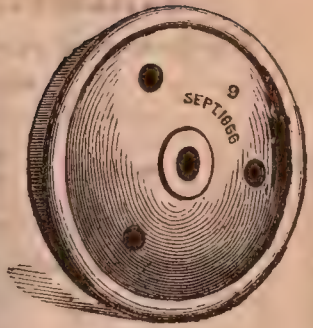
We refer by permission to

H. RIDDLE, Esq., General Superintendent Erie Railway.
H. G. BROOKS, Esq., Supt. Motive Power and M'y E. R'way.
T. W. KENNARD, Esq., Chief Eng. Atlantic & G. West'n R. R.
F. GRINNELL, Esq., Supt. Motive Power " " "
Col. BERTHOUD, Gen'l Supt. Morris & Essex R. R.
R. E. RICKER, Esq., Gen'l Supt. Central R. R., New Jersey.
L. CROSSMAN, Esq., Supt. Motive Power, Central R. R., N. J.
WOLCOTT JACKSON, Esq., General Supt. N. J. R. R. & T. Co.
JOHN HEADDEN, Esq., Supt. Motive Power " " "



WASHBURN PATTERN.





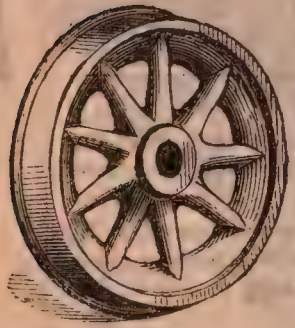
W. W. SNOW'S PATTERN.

CAR WHEELS,

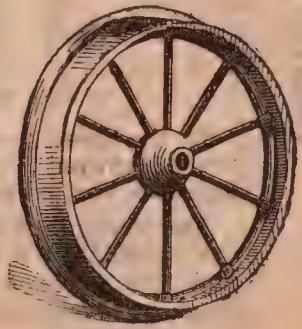
MADE BY

Ramapo Wheel and Foundry Co.,

RAMAPO, N. Y.



HOLLOW SPOKE.



CONSTRUCTION.

STRENGTH OF CAR WHEELS OF RICHMOND IRON,

May be seen by examining the following tests of Wheels, made at ALTOONA, by the officers of the Pennsylvania Railroad, July 17, 1867.

No.	Makers.	When Made.	Tread.	Size.	Weight.	* Blows to Crack Plate.			Total No. of Blows.	Chill.	Class of Wheel.
	Name omitted.	1855	B. T.	33-in.	496 lbs.	49	24	13	86	3/8	Freight.
2	" "	1867	"	33-in.	631 "	21	21	45	87	3/8	Sleeper.
3	" "	1867	"	33-in.	546 "	9	7	23	39	1/2	Freight.
4	RAMAPO . . .	1867	N. T.	33-in.	**519** "	**59**	**152**	**80**	**291**	3/8	Pass.
5	Name omitted.	1863	B. T.	33-in.	549 "	36	28	..	64	3/8	Freight
6	" "	1867	"	32-in.	513 "	51	43	..	94	5/8	Pass.
7	" "	1867	"	33-in.	510 "	20	9	12	41	5-16	Freight.

* Each wheel was tested in three places, if not destroyed by previous blows.

By the blows given, the wheels, with the exception of the Ramapo Wheel, were entirely destroyed. After many repeated blows, the centre of the Ramapo Wheel remained in, and it was left for the *drop* to *complete* its destruction.

The strength of Richmond Iron has been fully proved, by the continued use of it, by the South Boston Foundry Co. (Algers), in the manufacture of 15-inch Rodman guns, under the direction of General Rodman—as also in the 15-inch gun being tested by the English Government, at Shoeburyness, England.

Cut of a portion of an UNANNEALED CAR WHEEL, of RICHMOND IRON, made at RAMAPO, showing heavy chill on the tread; but the iron so ductile and strong that it can be forged. Taken from a photograph. Specimens forged in various forms can be seen at 24 Broadway, office of W. G. Hamilton, Agent Ramapo Wheel and Foundry Co.

Ramapo Wheel and Foundry Co.

WEAR OF CAR WHEELS.

There are in daily use on the 37,000 miles of railway in the United States, not less than 1,250,000 truck and car wheels, under 8,500 locomotives, 6,500 passenger cars, 2,700 baggage and express cars, and 160,000 freight cars. The available statistics show that passenger cars make an annual mileage of 28,400 miles, or 88 75-100 miles per day of 320 days per annum; the average load borne on each car wheel to be 3⅓ tons. With this load the average life of a wheel is 45,000 miles or 1 58-100 years. On trains running at express speeds, the average life does not exceed 10 months' service, while wheels under tender trucks have a life of 18 months. Under freight service in the State of New York, with an annual train mileage of 11,483,123 miles, transporting 75 5 tons of freight per train, the annual mileage per car was 14,649 miles, each wheel bearing an average load of 1.47 tons, which gives 3.08 years as the life of a freight wheel, corresponding with the experience of one of the principal roads in the State. But assuming that the average life of car wheels, under all kinds of service, as being five years, the total number of wheels worn out annually in the United States will not be less than 250,000. At an average cost of eighteen dollars per wheel, allowing one half for their value for the old wheel, the annual loss may be stated at two and a quarter millions of dollars. The proprietors of the Ramapo Wheel and Foundry Company, knowing the importance attached by Railway Managers to secure a car wheel which should give a better protection to lives and property, and by reason of longer wear give a greater measure of economy, established the RAMAPO FOUNDRY, for the purpose of making a superior car wheel, experience having shown that a wheel made entirely of the strongest irons, free from any admixture of old car wheels, makes a safer and stronger wheel. This conclusion has become so apparent to many railway men, that the use of anything but new metal in their passenger wheels is rigidly enforced, and if old wheels are used in making the mixture for freight car wheels, wheels thus made are branded O. W.; and many lines, to prevent their further use in the manufacture of car wheels, have the old wheels converted into bar iron or plates, while wheel founders themselves claim to use entirely new metal in all their work.

The appreciation of the quality of the wheels made at Ramapo has been such that the RAMAPO WHEEL has been taken as a standard of excellence, and adopted on some of the most prominent railways in the country for their passenger service.

To meet the growing demand for their wheels, the capacity of their works has been greatly increased, and keeping a stock of the standard sizes of wheels and axles on hand, they will hereafter be enabled to fill orders at shorter notice.

The following letter from Mr. Grinnell, Superintendent of Motive Power and Machinery of the Atlantic and Great Western Railway, is a fair exponent of the estimation in which the RAMAPO CAR WHEEL is held:

MEADVILLE, PA., *July* 25, 1868.

W. G. HAMILTON, ESQ.,
Agent Ramapo Wheel and Foundry Co.,
21 Broadway, New York:

DEAR SIR: After a continued trial of the Ramapo Wheel, under the heavy rolling stock of this road, I am convinced that they are superior to any other wheel which we have had in use.

I have paid particular attention to the durability of wheels made by different parties used in the trucks of our passenger engines and tenders. These engines weigh 36½ tons, and the tenders 20 tons, without fuel or water, thus subjecting the wheels under them to a severe test. Up to the present writing my records show that your wheels have made 50 per cent. more mileage than the average of other makers.* One year ago this month we received from the Jersey City Locomotive Works, 5 "Mogul" 8-wheeled freight engines weighing 42 tons. These engines had 36-inch Ramapo wheels on truck or "leading" axle. They have run, on an average, to the 1st of this month, 23,000 miles one of them 29,000, and the wheels are still good. Any one acquainted with this class of locomotive is aware that these leading wheels are subjected to severe wear, and some 60 locomotives which have been built from the same drawings have steel tyres on them. When they came on to the road, not supposing that a chilled wheel could stand such service, I ordered steel tyres and wheels to replace them, but as yet have had no occasion to do so. They have about eight tons' weight on the two wheels.

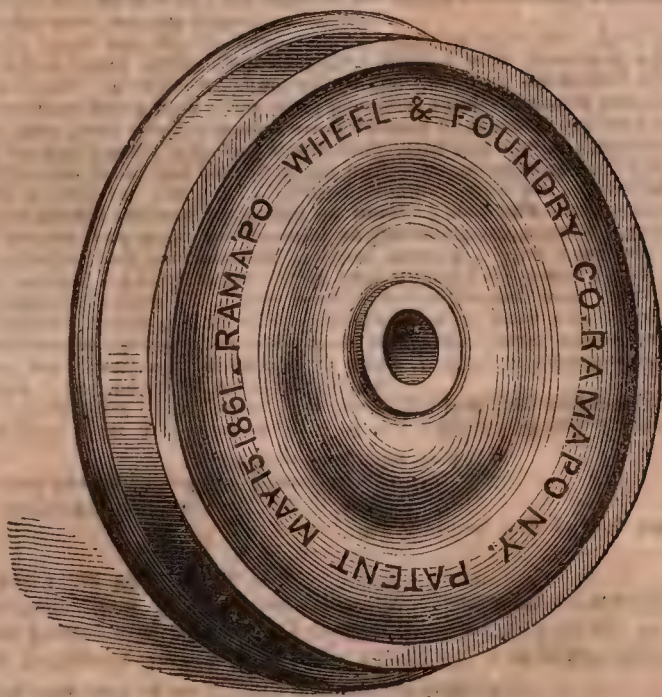
Believing as I do that you are offering the public a car wheel superior to all others, I take pleasure in giving you the result of my experience in their use. Yours, truly,

(Signed) FRED'K GRINNELL,
Supt. M. P. and Machinery.

* About 2,000 Ramapo wheels were in service.—ED.

VIEW OF

ATWOOD-WASHBURN

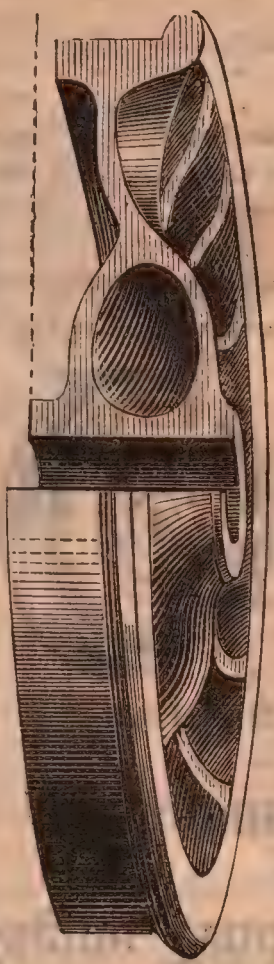


PATENT CAR WHEEL,

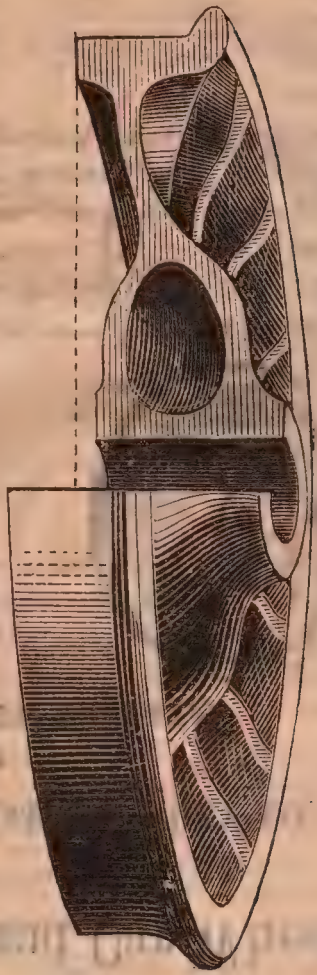
AS MADE BY

THE RAMAPO WHEEL AND FOUNDRY CO.

SECTION OF CAR WHEELS,



For Inside Journals.



For Outside Journals.

AS MADE BY

THE RAMAPO WHEEL AND FOUNDRY CO.

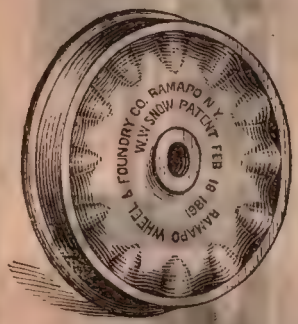
Ramapo Wheel and Foundry Co.

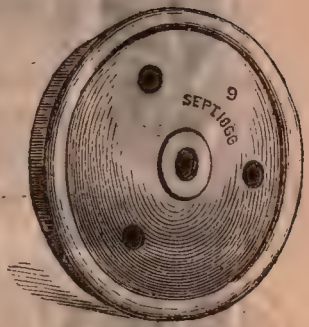
WEIGHT OF
Engine, Tender, and Car Wheels,

MADE BY THE

RAMAPO WHEEL AND FOUNDRY CO.

DOUBLE PLATE WHEELS.

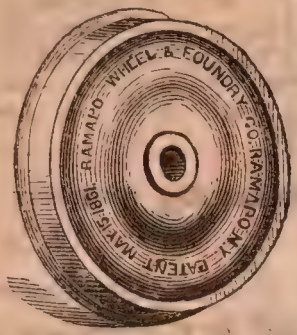


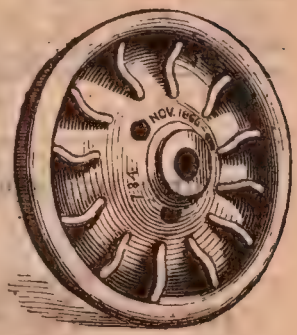


W. W. Snow's Patent, for Inside or Outside Bearings.

36-in.	diameter—	Extra heavy, for Engine Trucks		.....	640 lbs.
33-in.	"	"	"	.....	600 "
33-in.	"	Engines, Tenders, and Pass. Cars		....	530 "
30-in.	"	Extra heavy, for Engine Trucks		.....	520 "
30-in.	"	Engines, Tenders, and Cars		.....	480 "
28-in.	"	"	"	.....	440 "
26-in.	"	"	"	.....	380 "
24-in.	"	"	"	.....	320 "
20-in.	"	"	"	.....	280 "

ATWOOD-WASHBURN PATENT WHEELS.





36-in.	diameter—	Extra heavy, for Engine Trucks.....	620 lbs.
33-in.	"	" " " "	580 "
33-in.	"	Engine, Tender, and Passenger Cars.	530 "
33-in.	"	Ordinary and general use.....	500 "
33-in.	"	Light Freight Cars.....	480 "
30-in.	"	Extra heavy, for Engine Trucks.....	510 "
30-in.	"	Engines, Tenders, and Cars.....	480 "
30-in.	"	Light Freight Cars	450 "
30-in.	"	Coal Cars.....	430 "
28-in.	"	Engine Trucks and Tenders.....	430 "
26-in.	"	" "	380 "
26-in.	"	Coal Cars, heavy.....	365 "
26-in.	"	" light.....	345 "
24-in.	"	Engine Trucks and Tenders.....	330 "
20-in.	"	" "	280 "

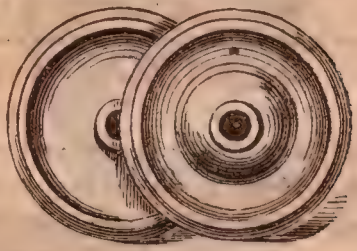
Decimal Equivalents of Inches, Feet, and Yards.

Fractions of an inch.	Decims. of an inch.	Decims. of a foot.	Ins.	Feet.	Yards.
	.0625	= .00521	1 =	.0833	= .0277
⅛	.125	= .01041	2 =	.1666	= .0555
	.1875	= .01562	3 =	.25	= .0833
¼	.25	= .02083	4 =	.3333	= .1111
	.3125	= .02604	5 =	.4166	= .1389
⅜	.375	= .03125	6 =	.5	= .1666
	.4375	= .03645	7 =	.5833	= .1944
½	.5	= .04166	8 =	.6666	= .2222
	.5625	= .04688	9 =	.75	= .25
⅝	.625	= .05208	10 =	.8333	= .2778
	.6875	= .05729	11 =	.9166	= .3055
¾	.75	= .06250	12 =	1.000	= .3333
	.8125	= .06771			
⅞	.875	= .07291			
	.9375	= .07812			
1 inch	1.00	= .08333			

Decimal Equivalents of Pounds and Ounces.

oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.
¼	.015625	3	.1875	6½	.40625	10	.625	13½	.84375
½	.03125	3½	.21875	7	.4375	10½	.65625	14	.875
¾	.046875	4	.25	7½	.46875	11	.6875	14½	.90625
1	.0625	4½	.28125	8	.5	11½	.71875	15	.9375
1½	.09375	5	.3125	8½	.53125	12	.75	15½	.96875
2	.125	5½	.34375	9	.5625	12½	.78125	16	1.
2½	.15625	6	.375	9½	.59375	13	.8125		

SINGLE PLATE WHEELS.



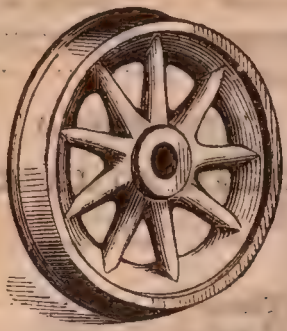
33-in.,	Single Plate—	Freight Cars, heavy	500 lbs.
33-in.,	"	" light	480 "
30-in.,	"	Engine Trucks and Tenders	460 "
30-in.,	"	Freight and Coal Cars	440 "
30-in.,	"	" "	420 "
28-in.,	"	Engine Trucks and Tenders	420 "
26-in.,	"	" "	375 "
26-in.,	"	Coal Cars	330 "
24-in.,	"	Engine and Tender Trucks	330 "
20-in.,	"	" "	280 "

USEFUL NUMBERS FOR RAPID APPROXIMATION

In Calculating Weights, Measures, etc.

Feet	× .00019	= miles.
Yards	× .0006	= miles.
Links	× .22	= yards.
Links	× .66	= feet.
Feet	× 1 5	= links.
Square inches	× .007	= square feet.
Circular inches	× .00546	= square feet.
Square feet	× .111	= square yards.
Acres	× 4840	= square yards.
Square yards	× .0002066	= acres.
Width in chains	× 8.	= acres per mile.
Cube feet	× .04	= cube yards.
Cube inches	× .00058	= cube feet.
U. S. bushels	× .0495	= cube yards.
U. S. bushels	× 1.2446	= cube feet.
U. S. bushels	× 2150.42	= cube inches.
Cube feet	× .8036	= U. S. bushels.
Cube inches	× .000466	= U. S. bushels.
U. S. gallons	× .13367	= cube feet.
U. S. gallons	× 231	= cube inches.
Cube feet	× 7.48	= U. S. gallons.
Cylindrical feet	× 5.874	= U. S. gallons.
Cube inches	× .004329	= U. S. gallons.
Cylindrical inches	× .0034	= U. S. gallons.
Lbs	× .009	= cwt.

ENGINE AND TENDER TRUCK WHEELS.



WITH HOLLOW SPOKES AND RIM.

36-in. diameter	.....	600 lbs.
33-in. "	.....	530 "
30-in. "	.....	480 "
28-in. "	.....	430 "
26-in. "	.....	380 "

CITY PASSENGER CAR WHEELS.

30-in. diameter,	3-in.	tread,	¾-in.	flange	.....	250 lbs.
30-in. "	2¼-in.	"	¾-in.	"	.....	225 "
30-in. "	2-in.	"	¾-in.	"	.....	200 "
28-in. "	2¼-in.	"	¾-in.	"	.....	190 "
26-in. "	2¾-in.	"	⅞-in.	"	.....	200 "
26-in. "	2-in.	"	¾-in.	"	.....	150 "

Useful Numbers for Rapid Approximation.

CONTINUED.

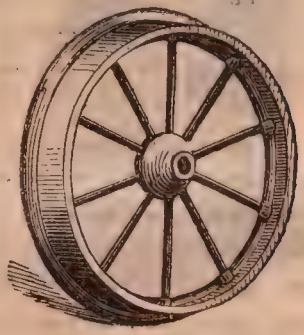
Lbs	×	.00045	= tons.
Cubic foot of water	×	62 5	= lbs. avoirdupois.
Cubic inch of water	×	.03617	= lbs. avoirdupois.
Cylindrical foot of water	×	49.1	= lbs. avoirdupois.
Cylindrical inch of water	×	.02842	= lbs. avoirdupois.
U. S. gallons of water	×	13.44	= 1 cwt.
U. S. gallons of water	×	268.8	= 1 ton.
Cubic feet of water	×	1.8	= 1 cwt.
Cubic feet of water	×	35 88	= 1 ton.
Cylindrical foot of water	×	6	= U. S. gallons.
Column of water, 12 in. high, 1 in. diameter			= .341 lbs.
183.346 circular inches			= 1 square foot.
2200 cylindrical inches			= 1 cubic foot.
French metres	×	3.281	= feet.
Kilogrammes	×	2.205	= avoirdupois lbs.
Grammes	×	.002205	= avoirdupois lbs.

WEIGHT OF METALS.

Wrought Iron.

Cube inches	×	.28	= lbs. avoirdupois.
Cube inches	÷	.100	= qrs.
Thickness of plates in inches	×	40	= lbs. per square foot.
Thickness of plates in eighths	×	5	= lbs. " "
Thickness of plates in tenths	×	4	= lbs. "

CONSTRUCTION WHEELS.



24-in.	diameter,	3-in.	tread,	¾-in.	flange	.....	200 lbs.
24-in.	"	2-in.	"	¾-in.	"	.....	140 "
20-in.	"	5-in.	"	1⅛-in.	"	.....	160 "
20-in.	spoke,	5-in.	"	1½-in.	"	.....	100 "
20-in.	"	2½-in.	"	¾-in.	"	.....	120 "
16-in.	"	2-in.	"	¾-in.	"	.....	70 "

CHILLED TIRE FOR DRIVING WHEELS.

From 36 to 60 inches diameter.

WEIGHT OF METALS—Continued.

Wrought Iron.

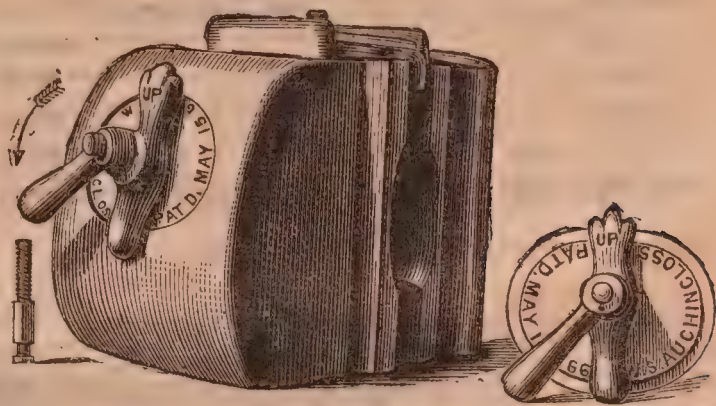
Sectional area in inches.....	× 3.34	= lbs.	per lineal foot.
Sectional area in eighths.....	× .052	= lbs.	" "
Sectional area in inches.....	× 10	= lbs.	per lineal yard.
Lbs. per lineal yard	× .7857	= tons	per mile run.
Diameter of round iron in inches squared	× 2.64	= lbs.	per foot run.

Various Metals.

Multipliers to convert the weights as found above into the weights of other metals.

Weight of wrought iron.	× .92	= weight of	zinc.
" "	× .93	= "	cast iron.
" "	× .94	= "	tin.
" "	× 1.01	= "	steel.
" "	× 1.09	= "	brass.
" "	× 1.15	= "	copper.
" "	× 1.48	= "	lead.
Cube inches	× .253	= lbs. of	zinc.
" "	× .26	= "	cast iron.
" "	× .263	= "	tin.
" "	× .282	= "	steel.
" "	× .3	= "	brass.
" "	× .32	= "	copper.
" "	× .41	= "	lead.
Miles	× .87	= knots.	
Knots.....	× 1.15	= miles.	
Feet per minute.....	× .01	= knots per hour.	

CAR CASTINGS FOR FREIGHT AND PASSENGER CARS.



W. S. Auchincloss's Patent Axle Box and Cover, Combining economy of first cost, saving in oil, easy removal of the cover for inspection of journal, and almost entire prevention of loss of the cover.

HYDRAULIC WHEEL PRESSES.

For putting on or taking off car wheels—adapted to power or hand pressure—cast from gun metal iron.

Wheels fitted to Axles, Wheels bored to Standard Gauges. Hammered and Rolled Car Axles.

WEIGHTS OF VARIOUS ARTICLES.

Weight per Bushel of different Grains, etc.

Barley	48 lbs.	Hemp seed	48 lbs.
Beans	63 "	Oats	32 "
Buckwheat	46 "	Peas	64 "
Blue grass seed	14 "	Rye	56 "
Corn	56 "	Salt	80 "
Clover seed	60 "	Timothy seed	56 "
Dried apples	22 "	Wheat	60 "
Dried peaches	33 "	Potatoes (heaped)	60 "
Flax seed	56 "		

Weight per Barrel of different Articles.

Flour	196 lbs.	Fish	200 lbs.
Salt	280 "	Soap	256 "
Beef	200 "	Cement	300 "
Pork	200 "		

Miscellaneous Articles.

1 chaldron, 36 bushels, or	57¼ cubic feet.
1 perch of stone	16½ "
1 hand	4 inches.
1 span	9 "
1 fathom	6 feet.
1 ton (2240 lbs.) cured hay	425 cubic feet.
1 ton of hay in mow	414.37 " or a cube of 7½ feet.

WEIGHTS OF VARIOUS ARTICLES.

Miscellaneous Articles—Continued.

Hay, as usually delivered	5	lbs. per cubic ft.
" well pressed	8	" "
Straw, loose	3½	" "
" well pressed	5½	" "
1 gallon of water	8.33	lbs.
1 " oil	7¾	"
1 " molasses	11⅔	"
1 " alcohol	6.96	"
1 " spirits turpentine	7.31	"
1 firkin of butter	56	"
1 keg of powder	25	"

Sizes of Drawing Paper.

Antiquarian	52 × 31 ins.	Superroyal	27 × 19 ins.
Double Elephant	40 × 26 "	Royal	24 × 19 "
Atlas	33 × 26 "	Medium	22 × 17 "
Columbian	34 × 23 "	Demy	20 × 15 "
Elephant	28 × 22 "	Cap	13 × 16 "
Imperial	30 × 21 "		

Tracing Paper.

Double crown	30 × 20 ins.
Double double crown	40 × 30 "
Double double double crown	60 × 40 "

WEIGHTS, IN POUNDS, OF VARIOUS ARTICLES,

As Rated by Railway Companies, when their Weights cannot otherwise be ascertained.

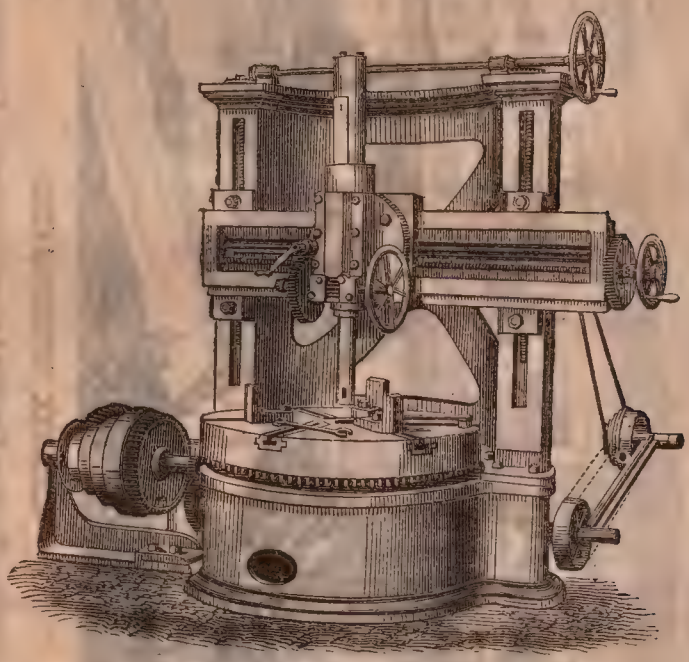
		POUNDS.
Ashes, Pot or Pearl	Barrel	450
Apples, and Barrelled Fruits	Barrel	200
Do.	Bushel	50
Barley	Bushel	45
Beef, Pork, Bacon	per Hhd	1,000
Butter, Tallow, Lard	per Bbl	333
Salt Fish and Meat	per Firkin	100
Bran, Feed, Shipstuffs, Oats	Bushel	35
Buckwheat	Bushel	48
Bricks, common	Each	5
Bark	Cord	2,000
Charcoal	Bushel	22
Coke, and Cake Meal	Bushel	40
Clover Seed	Bushel	62
Eggs	Barrel	200
Fish and Salt Meat	Per Firkin	100
Flour and Meal	Per Bushel, 56 lbs., Barrel	216
Grain and Seeds, not stated	Bushel	60
Hides (green)	Each	85
Do. (dry), Salted or Spanish	Each	33
Ice, Coal, Lime	Bushel	80
Liquors, Malt and Distilled	Barrel	350
Do.	Per Gallon	10
Lumber—Pine, Poplar, Hemlock	Ft. B. M.	4
Do. Oak, Walnut, Cherry, Ash	Ft. B. M.	5
Nails and Spikes	Keg	106
Onions, Wheat, Potatoes	Bushel	60
Oysters	Per Bushel. 100 lbs., per 1,000	350
Plastering Lath	Per 1,000	600
Rosin, Tar, Turpentine	Barrel	300
Sand, Gravel, etc	Per Cubic Ft.	150
Shingles	Per M., Short, 900 lbs., Long	1,400
Salt	Per Bushel	70
Stone, Undressed	Perch	4,000
Do. Dressed	Cubic Ft.	180
Timothy and Light Grass Seed	Bushel	40
Wood—Hickory	Cord	4,500
Do. Oak	Cord	3.500

The Ramapo Wheel and Foundry Co.

HAVE

WHEEL BORING AND TURNING MACHINE,

Built for them by



MESSRS. BEMENT & DOUGHERTY, PHILA.

With this superior Machine, the RAMAPO WHEEL AND FOUNDRY CO. have bored 60 car wheels in ten hours.

WHEELS FITTED.

☞ Hammered and Rolled Axles furnished at short notice.

Ramapo Wheel and Foundry Co.

LENOX FURNACE.

BERKSHIRE COUNTY, MASS.—PROPERTY OF COFFINGS, CHURCH & TAYLOR.

RICHMOND IRON WORKS,

MANUFACTURERS OF

CHARCOAL PIG IRON,

FROM BROWN HEMATITE ORES.

G. S. ROBBINS, *President, Salisbury, Ct.*
GEORGE COFFING, *Treasurer, Richmond, Mass.*

Iron is assorted in numbers as follows:

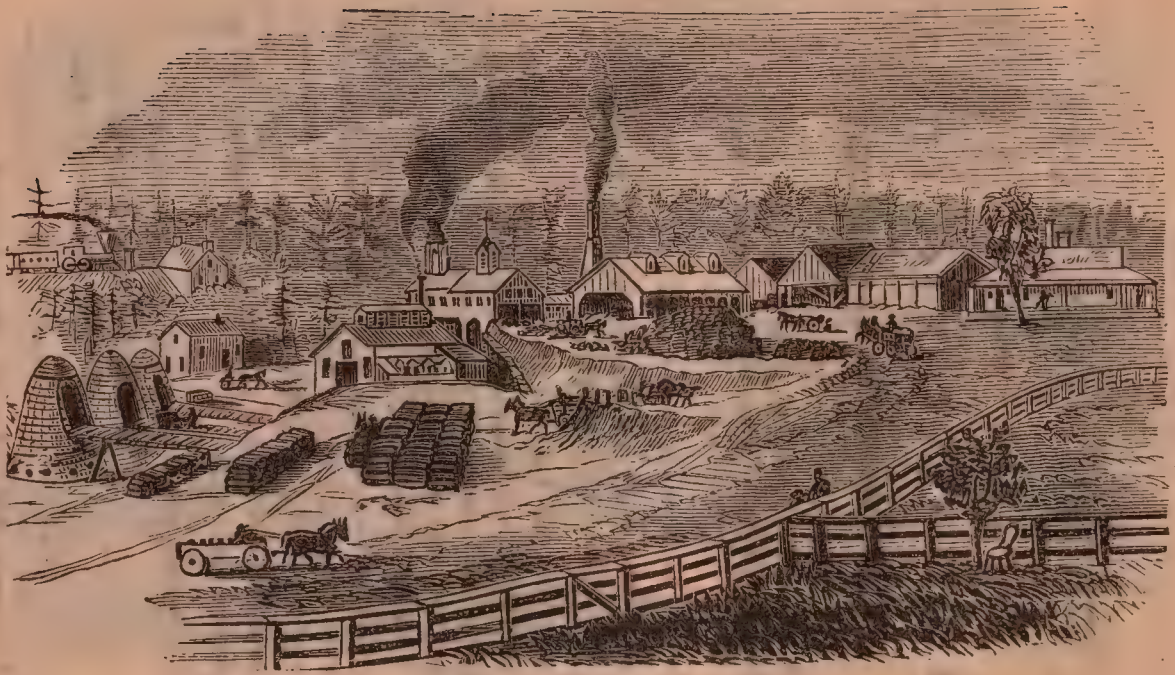
No. 1, SOFT No. 2, HARD No. 2, No. 3, MOTTLED, AND WHITE.

No. 1 and Soft No. 2 are of the lowest and softest quality, and are used for general foundry purposes; these numbers are celebrated for the amount of "*old scrap*" that can be melted with them; they also make an extra forge iron. Hard No. 2 and No. 3 are used together, and possess the properties necessary for a superior CAR WHEEL. No. 3 has more of the chilling properties than Hard No. 2. Where more than an ordinary depth of chill is required, the Mottled or White Iron is used in connection with Hard No. 2 and No. 3. Mottled and White are used for malleable work.

Address all communications to

RICHMOND IRON WORKS,
West Stockbridge, Mass.

Ramapo Wheel and Foundry Co.



RICHMOND IRON WORKS.

RICHMOND FURNACE, RICHMOND, BERKSHIRE COUNTY, MASS.

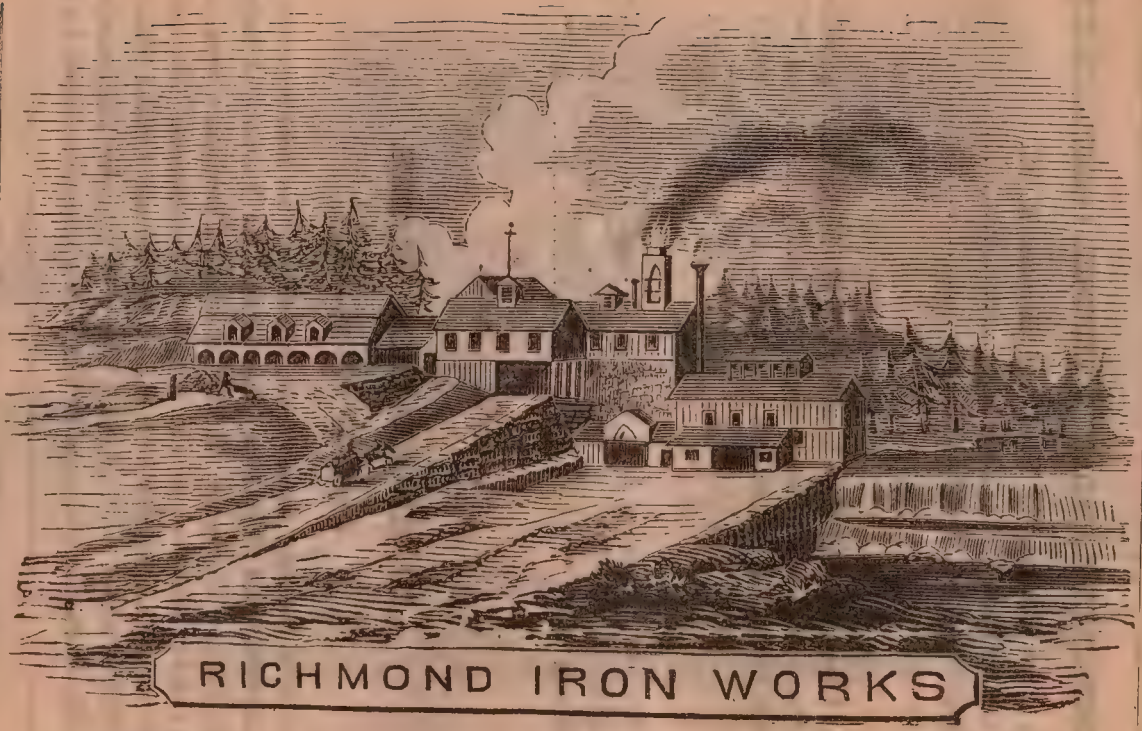
DISTANCES FROM RICHMOND IRON WORKS.

To New York—Via N. Y. and Harlem R. R., to Chatham	128 miles.
Chatham to Richmond	18 "
	146 "
Via Housatonic R. R.—New York to Bridgeport	49 miles.
Bridgeport to West Stockbridge	93 "
West Stockbridge to Works	2½ "
	114½ "
Albany to Richmond Iron Works	41 miles.
Boston " "	159 "
Hudson " "	35 "

RICHMOND IRON WORKS.

Its Rise and Progress.

One of the first three furnaces built in this country for the manufacture of Pig Iron, was erected at Furnace Village, Salisbury, Connecticut. This took place a few years previous to the breaking out of the American Revolution. The proprietor was an Englishman, and at the commencement of hostilities returned to England. The property was then confiscated, taken possession of by the Government, and used by it



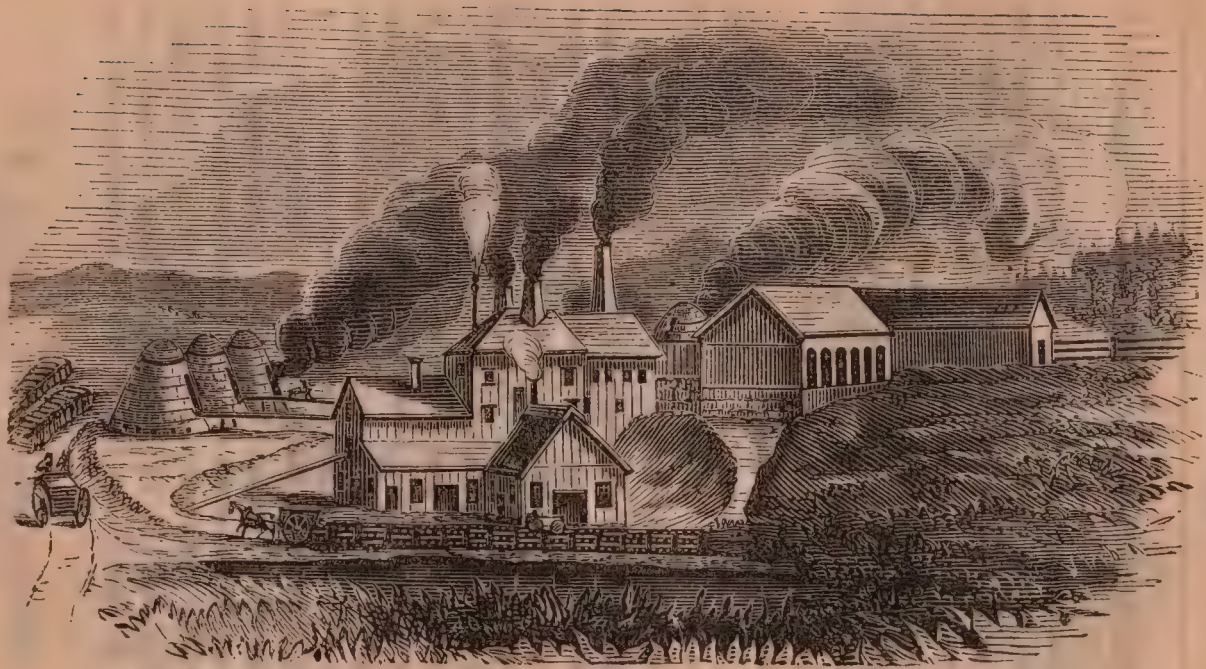
VAN DEUSENVILLE FURNACE, VAN DEUSENVILLE, BERKSHIRE COUNTY, MASS.

RICHMOND IRON WORKS—Continued.

for the manufacture of pig iron during the war, for various purposes. At the close of the war, this furnace property was sold by the Government, and continued to change hands until 1807, when John M. Holley and John C. Coffing, two young men of the town, associated themselves together, under the firm name of Holley & Coffing, and bought the Works. This was the commencement of Holley & Coffing's career as iron manufacturers.

Their success in this business, and the increased demand for this iron, induced them, from time to time, to erect in other parts of Salisbury extensive works for the manufacture, not only of cast, but of wrought iron.

The enterprise and great energy of this firm had very much to do in developing the qualities of this iron, and in establishing its reputation; the business being nearly forty years vigorously prosecuted by Mr. John C. Coffing, the surviving partner of the firm. While in the midst of their successful operations in Salisbury, about the year 1827, the attention of Holley & Coffing was called to the Hematite ores of Berkshire county, Mass. After a thorough examination and careful trial of these ores, they were satisfied that the iron made from them was of a very superior quality. These experiments caused the erection of the Richmond Furnace, in the town of Richmond, Berkshire county, Mass., in the year 1829, under the name of Gates, Pettee & Co. This name was changed by an act of the Legislature, in 1842, to "THE RICHMOND IRON WORKS." In 1834 Mr. Coffing, of the firm of Holley & Coffing, built the



RICHMOND IRON WORKS.

CHESHIRE FURNACE, BERKSHIRE COUNTY, MASS.

RICHMOND IRON WORKS—Continued.

Van Deusenville Furnace in Great Barrington, which was under the management of Phineas Chapin & Co. and others until 1844, when the property was bought by "THE RICHMOND IRON WORKS." In 1863 these works bought the Cheshire Furnace property, giving them three furnaces, of a daily capacity of nearly thirty tons. The fuel used is all charcoal, and the iron made is exclusively from the Hematite ores owned and controlled by the Richmond Iron Works.

One of these mines has been worked more than a century, and at an early day the ore was used in the manufacture of steel of a superior quality. The combined qualities of the Richmond Iron are not surpassed by any made. Its general use in the construction of the best CAR WHEELS, its great excellencies in machinery castings, and its remarkable adaptation to ordnance purposes, attest its superiority, and warrant its unparalleled reputation. The management of these works, and the general supervision of them, together with the manufacturing department, were attended to, personally, by two of the sons of the late John C. Coffing, the eldest of whom, John H. Coffing, has had forty years' experience in this business, and has devoted the whole of the active portion of his life to the manufacture of these celebrated irons.

THE RAMAPO WHEEL AND FOUNDRY COMPANY being supplied with the Richmond Irons (Mr. George Coffing, of the Richmond Works, being President of the Company, and Mr. G. Church, Treasurer), will exert themselves to maintain the supremacy of this famous iron in the quality of the wheels made by them.

RICHMOND IRON WORKS—Continued.

ANALYSIS OF THREE SAMPLES OF IRON ORE AND ONE OF LIMESTONE, from Richmond Iron Mines, made by Prof. Chas. T. Jackson, M. D., State Assayer, Feb. 16th, 1867.

No. 1.—	Water	12.0	
	Silicious matter	4.3	
	Peroxide of iron	79 0	= 55 3-10 per cent. iron.
	Oxide of manganese	4.0	
	Lime and loss	0.7	
		100.0	

No traces of sulphur, phosphorus, or other injurious ingredients, were found in this ore.

No. 2.—	Water	9 0	
	Silicious matter	34.5	
	Peroxide of iron	51.5	= 36 5-100 per cent. iron.
	Lime	1.5	
	Oxide of manganese	3.5	
	Loss	0.5	
		100.0	

No sulphur, phosphorus, or other injurious ingredients, were found in this ore.

No. 3.—	Water	11.80	
	Silica	7.00	
	Peroxide of iron	77.30	= Iron 54 1-10 per cent.
	Oxide of manganese	3.40	
	Traces of lime and loss	0.50	
		100.00	

No sulphur, phosphorus, or other injurious ingredients, were found in this ore.

RICHMOND IRON WORKS—Continued.

No. 4.—Limestone, to be used as a flux.

Moisture	0.56	
Carbonate of lime	89 00 pure lime	= 49.94 pr. ct.
Silica	4.00	
Carb. magnesia	1.44	
	100.00	

ANALYSIS OF RICHMOND IRON, by Professor Charles T. Jackson.

Nos. 2 and 3.

Iron	96.040	96.992
Carbon	3.062	2.800
Silicon	0.898	0.208
	100.000	100.000

RESULTS OF TESTS OF TENSILE STRENGTH per square inch of Section of Richmond Irons, made at South Boston Iron Company.

REMELTED RICHMOND IRON.

Density	7.320	Tensile Strength	40.242
"	7.302	"	39.094
"	7.308	"	39.922
"	7.320	"	40.699

RICHMOND PIG IRON.

Density	7.2578	Tensile Strength	24.390
"	7.2054	"	24.114
"	7.2080	"	25.086
"	7.2142	"	25.175
"	7.2505	"	28.442

LETTER FROM BRIG.-GEN. T. J. RODMAN.

ROCK ISLAND ARSENAL, *June* 17, 1867.

WILLIAM G. HAMILTON,
Ramapo Wheel and Foundry Co.,
Ramapo, N. Y.:

SIR: Yours of the 12th inst., relative to quality of Richmond iron, is received. In reply I would state that the Richmond iron made by Mr. Coffing, near the village of Richmond, Mass., has been used for the last few years in the manufacture of cast-iron cannon, made under my general supervision.

I have tested this iron in various ways; but more generally in samples cut from gun heads, one or more samples being taken from every gun head, and tested.

I consider this iron equal to any that I have tested, *in the cast state.* I do not now remember that I have tested it *in the wrought state.*

Its tenacity in gun heads runs from, say, 31,000 to 36,000 lbs. per square inch, generally. Occasionally a specimen will go above, and another below these figures—30,000 lbs. having been fixed as the minimum tenacity that will be received in a gun.

I have not tested this iron either in car wheels or machinery, but I should judge it to be a superior iron for these purposes.

Very respectfully, your obedient servant,

T. J. RODMAN,
Lieut.-Col. of Ordnance,
Bvt. Brig.-Gen. U. S. A.

LETTER FROM SOUTH BOSTON IRON CO.,

As to Value of Richmond Iron.

BOSTON, *May* 6, 1865.

GEO. COFFING, Esq.,
Treas. Richmond Iron Works,
Richmond, Mass.:

DEAR SIR: A few days since, when you were at our works, in the course of conversation you incidentally requested us to give you a statement of our opinion of the RICHMOND IRON as compared with other irons, etc.

The fact of our having used it exclusively for more than two years past (and that we still continue to do so), in preference to all other irons, for the fabrication of heavy guns, gives stronger evidence than any words as to our opinion of its qualifications for this purpose. Major Rodman, the present Constructor of Ordnance, has tested this iron in various ways—its extensibility, its compressibility, its tensile and transverse strength; and, if we understand him, gives it the preference over other irons for ordnance purposes. This derives importance from the fact, that all irons used for casting ordnance for our Government (Ordnance Department), must first be submitted to, and approved by him.

We have spoken of the Richmond Iron in connection with the manufacture of guns, because our experience with it has been mainly for this purpose, but we have no hesitation in saying that, in our opinion, it is equally well adapted for any pur-

LETTER FROM SOUTH BOSTON IRON CO.

Continued.

pose that requires soundness of casting, uniformity of result, and great strength and endurance.

After remelting in an air furnace, with a density of 7.26 to 7.30, we attain a strength of from 34,000 to 37,000 lbs. (in some instances 40,000 lbs.) per square inch. We should say, iron of a density as above, corresponds in appearance of fracture to your Nos. 3 and 4, or mottled pig. If you are not familiar with densities of irons by figures, you can associate it in this manner, and so form a comparative opinion.

In our opinion, a great excellence of the RICHMOND IRON consists in its uniformity of working, and in its great margin of safety. Now, with all circumstances conspiring favorably, we have attained results with other irons, if not entirely as good, nearly so, and within the limit of density and tenacity prescribed by the present standard for ordnance purposes; but circumstances will not always conspire favorably—furnaces get out of order, fuel is not always just right, or we have dog-days, which trouble air-furnaces, etc. If the iron you are working affords no margin of safety, its condition being a little too high or a little too low, you lose your work. This is an objection to the use of that iron.

Now, what we mean by a greater margin of safety in the RICHMOND IRON is, that it affords greater latitude in this respect than other irons, and this is a very important element.

The above is our candid opinion in regard to the RICHMOND

LETTER FROM SOUTH BOSTON IRON CO.

Continued.

IRON, and we give it to you frankly, although, as large consumers of this iron, it might not seem to our interest to do so; but we have been in all respects honorably used by you, and mean to reciprocate, and if you have any other inquiry as to our opinion of your iron, we shall be happy to answer it.

Very respectfully, your obedient servants,

THE SOUTH BOSTON IRON CO.,

By EDWARD REED.

Since the above letter was written, the South Boston Iron Co. have used more than 4,000 tons of the Richmond Iron, and continue to use it.

NOTES ON CAST IRON.

FROM REPORTS OF MAJOR WADE.

Prolonged exposure of liquid iron to an intense heat augments the cohesive power of the iron; this power increases as the times of exposure, up to some (not well ascertained limit, and if extended beyond that limit, the strength of the iron is thereby diminished. Transverse strength of iron is augmented by rapid cooling in small castings. Tensile strength is increased by slow cooling in large masses. Specific gravity is higher in the small castings, cooled rapidly.

A convenient method for determining the condition of iron while in fusion, and whether it has arrived at a proper condition for casting or should be held longer in fusion, is found in dipping from the melted pool of iron and casting into small bars, 10 ins. long, and 1½ ins. square at one end and tapering to a point at the other end, cast vertically in green sand moulds, point downward, and cooled rapidly; the first one to be cast as soon as the iron is all melted, the others at intervals, as may be judged proper. They are then broken in different places, the condition of the iron being judged by appearance of the several fractures. The fractures will vary from white at the small end to dark gray at large end; the bars cast at the later periods of fusion will exhibit the white at a greater distance from the small end, and the mottle, bright and lighter shades, advancing towards the large end. A practised eye would readily note the changes in the metal, and determine the proper time for casting.

TABLE

Showing the Time at 80 different places, when it is 12 o'clock at New York City; also, column showing Difference of Time from New York.

NEW YORK CITY, 12 M.					FAST.			SLOW.		
PLACES.	H.	M.	S.		H.	M.	S.	H.	M.	S.
Albany, N. Y.	12	1	1	p.m.	..	1	1	..	..	..
Annapolis, Md.....	11	50	4	a.m.	..	..	..	..	9	56
Augusta, Me.....	12	16	40	p.m.	..	16	40	..	..	..
Baltimore, Md.....	11	49	33	a.m.	..	..	..	..	10	27
Bangor, Me.	12	20	52	p.m.	..	20	52	..	..	..
Boston, Mass.....	12	11	46	p.m.	..	11	46	..	.	..
Buffalo, N. Y.....	11	40	20	a.m.	..	..	..	..	19	40
Cambridge, Mass..	12	11	30	p.m.	..	11	30	..	..	..
Charleston, S. C...	11	36	18	a.m.	..	..	..	..	23	42
Chicago, Ill.	11	5	29	a.m.	..	..	..	..	54	31
Cincinnati, Ohio...	11	18	2	a.m.	..	..	..	..	41	58
Cleveland, Ohio ..	11	28	36	a.m.	..	..	..	..	31	24
Clinton, N. Y.....	11	54	23	a.m.	..	..	..	..	5	37
Columbus, Ohio...	11	23	48	a.m.	..	..	..	..	36	12
Concord, N. H....	12	10	4	p.m.	..	10	4	..	..	..
Detroit, Mich.	11	23	50	a.m.	..	..	..	..	36	10
Dover, N. H.....	12	12	24	p.m.	..	12	24	..	..	..
Eastport, Me.....	12	28	16	p.m.	..	28	16	..	..	..
Fall River, Mass..	12	11	32	p.m.	..	11	32	..	..	..
Frankfort, Ky.	11	17	20	a.m.	..	..	..	..	42	40
Gloucester, Mass..	12	13	21	p.m.	..	13	21	..	..	..
Greenwich, Eng...	4	56	..	p.m.	4	56	..	..	..	..
Halifax, N. S.....	12	41	33	p.m.	..	41	33	..	..	..
Halowell, Me.....	12	16	40	p.m.	..	16	40	..	..	..
Harrisburgh, Pa...	11	48	40	a.m.	..	..	..	..	11	20

Table showing the difference of Time.

CONTINUED.

NEW YORK CITY, 12 M.					FAST.			SLOW.		
PLACES.	H.	M.	S.		H.	M.	S.	H.	M.	S.
Hartford, Conn....	12	5	17	p.m.	..	5	17	..	..	..
Havana, Cuba.....	11	26	29	a.m.	..	..	..	..	33	31
Key West, Fla....	11	28	50	a.m.	..	..	..	..	31	10
Leavenworth, Kan.	10	37	4	a.m.	..	..	..	1	22	56
Lexington, Ky.....	11	18	48	a.m.	..	..	..	..	41	12
Liverpool, Eng....	4	43	59	p.m.	4	43	59	..	..	..
Lockport, N. Y....	11	40	56	a.m.	..	..	..	..	19	4
London, Eng.....	4	55	36	p.m.	4	55	36	..	..	..
Louisville, Ky.....	11	14	..	a.m.	..	..	..	..	46	..
Lowell, Mass.....	12	10	44	p.m.	..	10	44	..	..	..
Memphis, Tenn. ..	10	55	28	a.m.	..	..	..	1	4	32
Milwaukee, Wis...	11	4	23	a.m.	..	..	..	..	55	37
Mobile, Ala.....	11	3	54	a.m.	..	..	..	..	66	6
Montpelier, Vt.....	12	5	36	p.m.	..	5	36	..	..	..
Montreal, C. E....	12	1	48	p.m.	..	1	48	..	..	..
Nantucket, Mass..	12	15	38	p.m.	..	15	38	..	..	..
Newark, N. J.....	11	59	20	a.m.	..	..	..	..	..	40
N. Bedford, Mass..	12	12	18	p.m.	..	12	18	..	..	..
Newburyp't, Mass.	12	12	32	p.m.	..	12	32	..	..	..
New Haven, Conn.	12	4	18	p.m.	..	4	18	..	..	..
N. London, Conn..	12	7	40	p.m.	..	7	40	..	..	..
New Orleans, La..	10	56	..	a.m.	..	..	..	1	4	..
Newport, R. I.....	12	10	46	p.m.	..	10	46	..	..	..
Niagara Falls, N.Y.	11	39	44	a.m.	..	..	..	..	20	16
Norfolk, Va.....	11	50	46	a.m.	..	..	..	..	9	14
Northamp'n, Mass.	12	5	30	p.m.	..	5	30	..	..	..
Omaha City, Ne...	10	32	4	a.m.	..	..	..	1	27	56
Oswego, N. Y.....	11	49	36	a.m.	..	..	.	..	10	24
Paris, France.....	5	5	21	p.m.	5	5	21	..	..	..
Philadelphia, Pa...	11	55	20	a.m.	..	..	..	..	4	40
Pike's Peak, Mo..	9	56	..	a.m.	..	..	..	2	4	..

Table showing the Difference of Time.

CONTINUED.

NEW YORK CITY, 12 M.					FAST.			SLOW.		
PLACES.	H.	M.	S.		H.	M.	S.	H.	M.	S.
Pittsburgh, Pa.....	11	35	52	a.m.	..	..	..	..	24	8
Portland, Me.	12	15	2	p.m.	..	15	2	..	..	..
Portsmouth, N. H.	12	12	57	p.m.	..	12	57	..	..	..
Providence, R. I...	12	10	25	p.m.	..	10	25	..	..	..
Provincet'n, Mass..	12	15	48	p.m.	..	15	48	.	..	..
Quebec, C. E.....	12	11	11	p.m.	..	11	11	..	..	..
Raleigh, N. C.....	11	40	48	a.m.	..	..	..	..	19	12
Richmond, Va.....	11	46	10	a.m.	..	..	..	..	13	50
Rochester, N. Y...	11	44	36	a.m.	..	..	..	..	15	24
Sacramento C. Cal.	8	50	9	a.m.	..	..	..	3	9	51
Salem, Mass. .	12	12	26	p.m.	..	12	26	..	..	..
Salt Lake City, Ut.	9	27	36	a.m.	..	..	..	2	32	24
San Francisco, Cal.	8	46	13	a.m.	..	..	..	3	13	47
Saratoga, N. Y....	12	1	..	p.m.	..	1	..	..	..	..
Savannah, Ga.....	11	31	39	a.m.	..	..	..	..	28	21
Springfield, Mass.	12	5	37	p.m.	..	5	37	..	..	..
St. Louis, Mo.....	10	54	59	a.m.	..	..	..	1	..	1
Syracuse, N. Y....	11	51	12	a.m.	..	..	..	..	..	48
Tallahassee, Fla...	11	17	36	a.m.	..	..	..	..	42	24
Toronto, C. W....	11	38	27	a.m.	..	..	..	..	21	33
Trenton, N. J.....	11	57	24	a.m.	..	..	..	..	2	36
Utica, N. Y.	11	55	8	a.m.	..	..	..	..	4	52
Washington, D. C.	11	47	48	a.m.	..	..	..	..	12	12
West Point, N. Y..	12	..	10	p.m.	..	..	..	..	..	..

TABLE for Foretelling the Weather through the Lunations of the Moon.

(Dr. Herschell and Adam Clarke.)

If the New Moon, the First Quarter, the Full Moon or the Last Quarter, enters—	In Summer.	In Winter.
Between midn'ht and 2 A. M.	Fair.	Hard frost, unless wind is S. or E.
Bet. 2 and 4 A. M.	Cold, fr't showers.	Snowy and stormy.
" 4 and 6 A. M.	Rain.	Rain.
" 6 and 8 A. M.	Wind and rain.	Stormy.
" 8 and 10 A. M.	Changeable.	Cold rain if wind is W., snow if E.
" 10 and 12 A. M.	Frequent showers.	Cold and high wind.
At 12 M. and 2 P. M.	Very rainy.	Snow or rain.
Bet. 2 and 4 P. M.	Changeable.	Fair and mild.
" 4 and — P. M.	Fair.	Fair.
" 6 and 8 P. M.	Fair if wind N. W., rainy if S. or S. E.	Fair and frosty if w'd is N. or W., rain or snow if S. or S. E.
" 8 and 10 P. M.	Do.	Do.
" 10 and midnight	Fair.	Fair and frosty.

Observations.—1. The nearer the time of the moon's change, first quarter, full, and last quarter, is to *midnight*, the fairer the weather during 7 following days. Range for this is from 10 at night till 2 next morning. 2. The nearer to *mid-day* the phases of the moon happen, the more foul or wet weather during the 7 days following. 3. The moon's change entering from 4 to 10 of the afternoon, may expect fair weather.

DISTANCE BY RAILROADS

Between important Places in the United States.

From New York to—

Albany	144	miles.
Baltimore, Md	184	"
Boston	236	"
Buffalo, via Hornellsville	423	"
" " Albany	442	"
Charleston, S. C.	788	"

Ramapo Wheel and Foundry Co.

DISTANCE BY RAILROADS—Continued

FROM NEW YORK TO

Chicago, via Albany, Buffalo, and Cleveland...	980	miles.
" " Buffalo and Canada	1043	"
" " Erie Railway and Cleveland.....	957	"
" " Philadelphia and Pittsburg.....	935	"
Cincinnati, via Albany and Buffalo.....	880	"
" " Erie R'y and A. & G. W R'y..	863	"
" Philadelphia and Pittsburg.....	807	"
Cleveland, via Albany and N. Y. Central.....	625	"
" " Erie Railway.....	602	"
" " Philadelphia and Pennsylvania..	580	"
Dunkirk.....	460	"
Indianapolis, via Albany, Buffalo, and Clevel'd.	911	"
" " Erie Railway and Cleveland..	888	"
" " Philadelphia and Pittsburg...	838	"
Louisville, via Dunkirk.....	994	"
" " Philadelphia	946	"
Milwaukee, Wis., via Dunkirk and Chicago ...	1047	"
Mobile, Ala.....	1432	"
Montreal, Canada.....	403	"
Niagara Falls, via Erie Railway.....	438	"
" " N. Y. Central.....	447	"
Philadelphia.....	87	"
Quebec, Canada.....	582	"
RAMAPO, New York, on Erie Railway.....	33	"
Richmond, Va.....	355	"
Rock Island, Ill.....	1139	"

DISTANCE BY RAILROADS—Continued.

FROM NEW YORK TO

St. Louis, via Dunkirk and Chicago	1242 miles.
Washington, D. C.	224 "

FROM BOSTON TO

Albany	200 miles.
Augusta, Maine	165 "
Baltimore	420 "
Buffalo	498 "
Charleston, S. C.	1018 "
Chicago, via Canada	1013 "
Cincinnati, via Cleveland	936 "
Halifax, N. S.	653 "
Montreal, Canada	322 "
New Orleans, La.	1828 "
New York, via Hartford	236 "
Philadelphia	323 "
Portland, Maine	105 "
Quebec, Canada	422 "
RAMAPO	269 "
Richmond, Va.	591 "
Savannah, Ga.	1143 "
St. Louis, via Chicago	1298 "
Washington, D. C.	460 "

FROM PHILADELPHIA TO

Baltimore	97 miles.
Boston	323 "
Buffalo	424 "

DISTANCE BY RAILROADS—Continued.

FROM PHILADELPHIA TO

Charleston	789	miles.
Chicago	847	"
Cincinnati, via Pittsburg and Steubenville	663	"
Cleveland, via Pittsburg	492	"
Detroit, Mich	766	"
Elmira, N. Y	275	"
Galena, Ill	1018	"
Harrisburg, Pa	106	"
Indianapolis, via Steubenville and Columbus	730	"
Louisville, " " " Cincinnati	796	"
" " Pittsburg and Ohio River	963	"
Milwaukee, " Cleveland	937	"
Mobile	1345	"
Montgomery, Ala	1148	"
New Orleans	1511	"
Niagara Falls	443	"
Pittsburg	353	"
Pottsville, Pa	93	"
Richmond, Va	268	"
RAMAPO	120	"
Rochester, N. Y	373	"
Rock Island, via Chicago	1028	"
Savannah, Ga	901	"
St. Louis, via Cleveland and Chicago	1132	"
" " Pittsburg and Indianapolis	1022	"
" " " " Cincinnati	1050	"

DISTANCE BY RAILROADS—Continued.

FROM PHILADELPHIA TO

Toronto, via Catawissa and Niagara	497 miles.
Washington, D. C.	137 "

FROM BALTIMORE TO

Boston	420 miles.
Charleston, S. C.	692 "
Chicago, via Wheeling and Cleveland	878 "
Cincinnati, via " " Central Ohio R. R.	629 "
" " " " Ohio River boat	763 "
Cleveland, " Baltimore and Ohio R. R.	523 "
" " Pennsylvania R. R.	469 "
Cumberland, Md.	178 "
Elmira, N. Y.	247 "
Harper's Ferry	82 "
Jonesboro', Tenn.	524 "
New York	184 "
Niagara Falls	415 "
Philadelphia	97 "
Pittsburg, via Pennsylvania R. R.	330 "
Raleigh, N. C.	342 "
RAMAPO	217 "
Rock Island, via Chicago	1059 "
Staunton, Va.	197 "
St. Louis, via Wheeling & Ohio & Miss. Rivers.	1459 "
Washington, D. C.	40 "
Wheeling, via Baltimore and Ohio R. R.	380 "
Williamsport, Pa.	169 "

DISTANCE BY RAILROADS—Continued.

FROM WASHINGTON, D. C., TO

Baltimore	40	miles.
Boston	460	"
Buffalo, N. Y	442	"
Charleston, S. C	652	"
Chicago, Ill	864	"
Cincinnati, Ohio	509	"
Cleveland, "	509	"
Corralles, Oregon (overland route)	3485	"
Detroit, Mich	684	"
Galveston, Texas	1800	"
Halifax, N. S.	1113	"
Memphis, Tenn	1476	"
Mexico, City of Mexico	2400	"
Montreal, Canada	627	"
New Orleans, La	1365	"
New York	224	"
Philadelphia	137	"
Quebec, Canada	772	"
RAMAPO	257	"
Salt Lake City	2672	"
San Francisco (overland)	3000	"
Santa Fé, New Mexico	2192	"
St. Louis, Mo	1040	"
St. Paul, Min	1345	"
Toronto, Canada	625	"

OVERLAND ROUTE.

Atchison to	Fort Kearney	260	miles.
" "	Denver, Colorado	650	"
" "	North Platte	876	"
" "	Green River	1,053	"
" "	Great Salt Lake City, Utah	1,256	"
" "	Bear River	1,340	"
" "	Boise City	1,649	"
" "	Virginia City	1,733	"
" "	Helena	1,853	"
" "	Sierra Nevada (summit)	2,085	"
" "	Sacramento City	2,225	"
" "	San Francisco	2,365	"

St. Louis to	Fort Kearney	598	miles.
" "	Fort Laramie	1,058	"
" "	Red Buttes	1,215	"
" "	Fort Bridger	1,493	"
" "	Bear River	1,528	"
" "	Fort Hall	1,684	"
" "	Fort Boisse	2,001	"
" "	Fort Walla-Walla	2,229	"
" "	Fort Vancouver	2,416	"
" "	Oregon City	2,446	"

SAILING DISTANCE FROM NEW YORK IN GEOGRAPHICAL MILES.

To Sandy Hook	18	miles.
" Nantucket Light	211	"
" Boston	302	"
" Halifax	666	"
" Cape Henlopen	149	"
" Philadelphia	252	"
" Cape Henry	276	"
" Baltimore	428	"
" Washington	434	"
" Norfolk	306	"
" Richmond	375	"
" Cape Hatteras	340	"
" Charleston	621	"
" Savannah	716	"
" Key West	1,484	"
" Havana	1,454	"
" New Orleans	2,129	"
" Vera Cruz	2,354	"
" Liverpool	3,084	"
" London	3,225	"
" St. Petersburg	4,420	"
" Havre	3,148	"
" San Francisco, via Panama	5,249	"
" " " Cape Horn	18,850	"
" Melbourne, via Cape of Good Hope	12,895	"
" Nangasaki, Japan	9,800	"

SAILING DISTANCE FROM NEW YORK.

Continued.

To Sandwich Islands, via Panama	7,157 miles.
" Canton, via Panama	10,000 "
" " " Good Hope	19,500 "

LATITUDE AND LONGITUDE OF PLACES.

PLACES.	LATITUDE.	LONGITUDE.
	D. M.	D. M.
Quebec	46.49 N.	71.16 W.
Halifax	44.38 "	63.65 "
Portland light	43 36 "	70.12 "
Buffalo	42.53 "	78.55 "
Chicago	42. 0 "	87.35 "
Newburyport light	42.48 "	70.49 "
Boston State House	42.21 "	71. 4 "
Nantucket light	41.23 "	70. 3 "
Newport	41.29 "	71.19 "
New York	40.42 "	74. 0 "
Philadelphia	39.57 "	75.10 "
Cape Henlopen	38.46 "	75. 4 "
Cincinnati	39. 6 "	84.27 "
St. Louis	38.36 "	89.36 "
Richmond	37.32 "	77 27 "
Washington City	38.53 "	77. 3 "
Baltimore	39.18 "	76.37 "
Cape Hatteras	35.14 "	75.30 "
Charleston light	32.42 "	79 54 "
Savannah	32. 5 "	81 8 "
Cape Florida	25.41 "	80. 5 "
Pensacola	30.24 "	87.10 "
Mobile	30.42 "	87.59 "
New Orleans	29.57 "	90. 0 "

From Greenwich.

LATITUDE AND LONGITUDE OF PLACES.

Continued.

PLACES.	LATITUDE.	LONGITUDE.
	D. M.	D. M.
San Francisco	37.47 N.	122.21 W.
Cape Horn	55.59 "	67.16 "
Porto Rico	18.29 "	66. 7 "
Cape Hayti	19.46 "	72.11 "
Havana	23. 9 "	82.22 "
Vera Cruz	19.12 "	96. 9 "
Mexico	19.26 "	99. 5 "
Porto Bello	9.34 "	79.40 "
Cape St. Augustine	8.21 S.	34.57 "
Rio Janeiro	22.56 "	43. 9 "
Buenos Ayres	34.36 "	58.22 "
Cape Horn	55.59 "	67.16 "
Valparaiso	33. 2 N.	71.41 "
London	51.31 "	0. 6 "
Liverpool	53.22 "	2.52 "
Greenwich	51.29 "	.....
Dublin	53.23 "	6.20 W.
Paris	48.50 "	2.20 E.
Marseilles	43.18 "	5.22 "
Florence	43.46 "	11.16 "
Rome	41.54 "	12.27 "
Naples	40.50 "	14.16 "
Berlin	52.31 "	13.24 "
Hamburg	53.33 "	9.56 "
Vienna	48.13 "	16.23 "
Constantinople	41. 1 "	28.59 "
Stockholm	59.21 "	18. 4 "
Copenhagen	55.41 "	12.34 "
St. Petersburg	59.56 "	30.19 "
Madrid	40.25 "	3.42 W.
Gibraltar	36. 6 "	5.20 "

From Greenwich.

LATITUDE AND LONGITUDE OF PLACES.

Continued.

PLACES.	LATITUDE.	LONGITUDE.
	D. M.	D. M.
Lisbon	38.42 N.	9. 9 W.
Palermo	38.12 "	15.35 "
Pekin	39 54 "	116.28 E.
Canton	23. 7 "	113.14 "
Cape of Good Hope	34.22 S.	18.30 "
Sidney, Australia	34. 0 "	151.23 "
Jerusalem	31.48 N.	37.20 "

Length of the day is equal double the time sun sets.
Length of the night is equal double the time the sun rises.

To Reduce Longitude into Time.

Divide the number of degrees, seconds, and minutes, by 15, and the quotient will be the time.

To Find Difference in Time between Two Places.

Divide the difference in longitude by 15, and quotient will be the difference.

AVERAGE DURATION OF IRON RAILS IN THE UNITED STATES.

Total number of miles of railway in operation from 1828 to 1860	31,185 miles.
Total tons of rails used (2,240 lbs. per ton).	3,689,149 tons.
Average time down for the whole number of miles	8 1-8 years.
Average number of tons laid per mile of track	118 3-10 tons per mile.
Average number of tons used in laying track	81 " "
Average number of tons used in renewing track	37 3-10 " "

Renewal of track equal to 46 per cent. of the quantity used in laying track.

Average annual wear equalled	5 2-3 per cent.
Average duration of rail	17 2-3 years.

LENGTH AND COST OF RAILROADS IN THE UNITED STATES, TO 1869.

(*From American R. R. Journal.*)

States.	Miles of Road.		Cost of Road and Equipment.	Gross Cost pr Mile.
	Total.	Open.		
Maine	944.19	559.67	$19,789,521	$35,259
New Hampshire	783.72	668.72	21,975,319	32,862
Vermont	643.59	603.59	24,347,149	40,337
Massachusetts	1,537.36	1,425 43	68,345,521	47,947
Rhode Island	121.47	121.47	5,006,665	41,217
Connecticut	782 66	641.23	23,064,859	35,969
New York	4,459.58	3,328.87	182,538,123	54,834
New Jersey	984.75	972.75	69,770,243	71,734
Pennsylvania	4,937.92	4,397.74	256,772,257	58,387

LENGTH & COST OF RAILROADS—Continued.

States.	Miles of Road.		Cost of Road and Equipment.	Gross Cost pr Mile.
	Total.	Open.		
Delaware and E. Maryland	362.90	242.94	$7,483,596	$21,818
Maryland (other than above)	654.95	457.45	28,520,899	62,409
West Virginia	605.85	364.75	23,404,100	61,381
Virginia	1,909.88	1,464.27	47,540,038	32,472
North Carolina	1,617.79	1,096.67	25,687,414	23,416
South Carolina	1,338.17	1,076.17	25,131,600	23,359
Georgia	1,977.60	1,574.60	31,369,075	19,916
Florida	613.20	440.20	9,294,000	21,123
Alabama	1,604.90	952.60	28,511,726	29,918
Mississippi	900.20	900.20	24 545,303	27,272
Louisiana	837.30	370.50	14,321,201	38,602
Texas	1,837.50	513.00	14,406,000	28,082
Arkansas	687.00	86.00	4,211,000	48,999
Tennessee	1,760.63	1,435 63	43,018,916	29,999
Kentucky	1,418.95	812.65	28,799,285	35,485
Ohio	4,053.44	3,351.97	169,014,101	50,422
Michigan	2,044.26	1,199.26	44,549,043	37,124
Indiana	3,246.10	2,600.10	104,229,226	40,089
Illinois	4,561.95	3,439.95	156,958,102	45,627
Wisconsin	1,773.60	1,234.60	48,469,301	39,246
Minnesota	1,758.00	571.50	18,460,000	32,272
Iowa	3,032.90	1,522.90	61,332,000	40,270
Nebraska	449.00	420.00	21,000,000	50,000
Wyoming T'rritory	560.00	510.00	41,800,000	81,961
Missouri	1,837.09	1,353.80	64,014,458	47,271
Kansas	1,123.00	648.00	30,840,000	47,599
Colorado	350,00	.....	350,000	....
Utah Territory	305.00	105 00	9,400,000	89,528
Nevada	390.00	320.00	25,600,000	80,000
California	2,091.50	468.50	30,336,000	64,682
Oregon	2,019.50	19.50	500,000	25,641
Total, Jan. 1, '69	62,917.10	42,272.18	$1,853,706,041	$43,849

LENGTH AND COST OF RAILROADS.

Continued.

RECAPITULATION BY SECTIONS.

STATES.	MILES OF ROAD.		COST OF ROAD AND EQUIPMENT.	GROSS COST PR MILE.
	Total.	Open.		
Six North-eastern States.....	4,812.99	4,020.11	$162,529,034	$40,430
Six Middle Eastern States	12,008.65	9,764.50	567,489,218	58,217
Five South-eastern States.....	7,456.64	5,651.91	139,022,129	24,597
Seven Gulf and S. Interior States..	9,046.48	5,070.58	157,813,431	31,121
Eleven N. Interior States, etc.....	24,439.34	16,852.08	760,666,231	45,128
Five West. States, etc..... ..	5,156.00	913.00	66,186,000	72,499
Ag. Jan. 1, '69....	62,917.10	42,272.18	$1,853,706,041	$43,849

PROGRESS OF RAILROAD CONSTRUCTION.

The first railroad built in the United States was in 1828, being the line built by the Quincy Company, extending from tide-water in Boston harbor to their quarry. In 1867 the aggregate length of railway lines in the United States is greater than is found in all other parts of the world together, and is equal to the length required, for a double track line, to girdle the earth at the equator.

YEARLY PROGRESS OF RAILROADS.

Year.	Miles.	Year.	Miles.	Year.	Miles.	Year.	Miles.
1828	3	1839	1,920	1850	7,475	1861	30,593
1829	28	1840	2,197	1851	8,589	1862	31,769
1830	41	1841	3,319	1852	11,027	1863	32,471
1831	54	1842	3,877	1853	13,497	1864	33,860
1832	131	1843	4,174	1854	15,672	1865	34,442
1833	576	1844	4,311	1855	17,398	1866	35,361
1834	762	1845	4,522	1856	19,251	1867	36,896
1835	918	1846	4,870	1857	22,625	1868	38,822
1836	1,102	1847	5,336	1858	25,090	1869	42,272
1837	1,421	1848	5,682	1859	26,755		
1838	1,843	1849	6,350	1860	28,771		

Chairs.

Wrought iron chairs weigh from 7 to 15 lbs. each; usual weight 11 lbs. each. One chair is required for each rail.

Spikes.

Hook spikes for rails, usually used, are 5 1-2 inches long by 9-16 inch. 190 spikes weigh 100 lbs.; 5,000 lbs. of spikes to one mile of single track.

AREA OF TERRITORIES.

Arizona	101,520	square miles.
Dakotah	325,000	"
Idaho	125,000	"
Indian Territory	65,171	"
New Mexico	154,780	"
Utah	120,000	"
Washington	51,144	"

AREA AND POPULATION OF THE UNITED STATES.

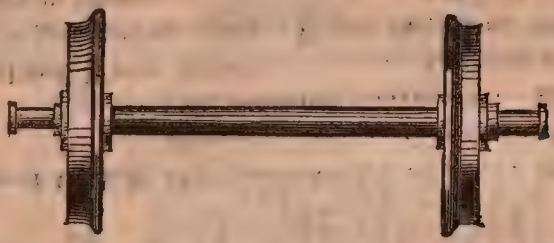
STATES.	AREA.	POPULATION.					
	Square Miles.	White Population, 1860.	Colored Population, 1860.	Civilized Indians, 1860.	Total Population, 1860.	Per ct. Increase fm. 1850.	M. of C.
Alabama....	50,722	526,271	437,770	160	964,201	24.96	6
Arkansas ..	52,198	324,143	111,259	48	435,450	107.46	3
California..	188,981	358,110	4,086	17,798	379,994	310.37	3
Colorado...	104,500	34,231	46	.....	34,277	.....	1
Connecticut	4,750	451,504	8,627	16	460,147	24.10	4
Delaware...	2,120	90,589	21,627	.....	112,216	22.60	1
Florida.....	59,248	77,747	62,677	.....	140,424	60.59	1
Georgia....	58,000	591,550	465,698	38	1,057,286	16.67	7
Illinois.....	55,410	1,704,291	7,628	32	1,711,951	102.06	14
Indiana....	33,809	1,338,710	11,428	290	1,350,428	36.63	11
Iowa	55,045	673,779	1,069	65	674,699	251.14	6
Kansas	81,318	106,390	627	189	107,206	.....	1
Kentucky .	37,680	919,484	236,167	33	1,155,684	17.64	9
Louisiana..	41,346	357,456	350,373	173	709,002	36.74	5
Maine	35,000	626,947	1,327	5	628,279	7.74	5
Maryland..	11,124	515,918	171,131	.....	687,049	17.84	5
Mass.	7,800	1,221,432	9,602	32	1,231,066	23.79	10
Michigan ..	56,451	736,142	6,799	6,172	749,113	88.38	6
Minnesota..	83,531	169,395	259	2,369	172,023	2730.72	2
Mississippi.	47,156	353,899	437,404	2	791,395	30.47	5
Missouri...	65,350	1,063,489	118,503	20	1,182,012	73.35	9
Nebraska ..	75,995	28,696	82	63	28,841	.....	1
Nevada....	81,539	6,812	45	.....	6,857	.....	1
N. Hamp..	9,280	325,579	494	.....	326,073	2.55	3
N. Jersey..	8,320	646,699	25,336	.....	672,035	37.27	5
New York.	47,000	3,831,599	49,005	140	3,880,735	25.29	31

AREA AND POPULATION OF THE UNITED STATES—Continued.

STATES.	AREA.	POPULATION.					
	Square Miles.	White Population, 1860.	Colored Population, 1860.	Civilized Indians, 1860.	Total Population, 1860.	Per ct. Increase fm. 1850.	M. of C.
N. Carolina	50,764	629,942	361,522	1,158	992,622	14.20	7
Ohio	39,964	2,302,808	36,673	30	2,339,502	18.14	19
Oregon	95,274	52,160	128	177	52,465	294.65	1
Penn	46,000	2,849,259	56,949	7	2,906,115	25.71	24
R. Island	1,366	170,649	3,952	19	174,620	18.35	2
S. Carolina	34,000	291,300	412,320	88	703,708	5.27	4
Tennessee	45,600	826,722	283,019	60	1,109,801	10.68	8
Texas	274,356	420,891	182,921	403	604,215	184,22	4
Vermont	10,212	314,369	709	20	315,098	0.31	3
Virginia	38,252						8
West Va.	23,000	1,047,299	548,907	112	1,596,318	12.29	3
Wisconsin	53,924	773,693	1,171	1,017	775,871	154.06	6

Population of U. S. in 1850 23,191,876
" " 1860 31,429,891
" " 1865, estimated 35,000,000
Total Land and Water Surface ..... 3,251,000 sq. miles.
Land = 3,010,370 sq. miles. Water, 240,630 sq. miles.
Land surface in States ..... 2,068,385 sq. miles.
" " " Territories ..... 942,615 "

DURABILITY OF CAR WHEELS.



It has been demonstrated by the wear of car wheels that a period of rest is requisite to insure great durability; that, by the continuous vibration of constant motion, the molecules of iron become in a measure disintegrated and eventually destroyed.

The truck wheels under engines and tenders, running an equal number of miles with passenger cars, will usually be found to be in a better condition, as the engine has more frequent and longer periods of rest.

The same rule applies to passenger cars running short trips as compared with express cars running long and continuous trips. At the same rate of speed the duration in mileage of the former is much greater, notwithstanding the more frequent action of the brakes upon them.

It has been proved by actual experiment that the RICHMOND IRON used in CAR WHEELS under express cars, being stronger than any known iron, withstands the excessive wear of continuous motion, and gives results much better than wheels made from other irons.

RAILS.

WEAR OF RAILS—IRON AND STEEL COMPARED.

The wear of rails, in making a comparison of duration, must bear relation not only to the total weight and speed of all trains running over the line, but also to the maximum weights upon a

wheel, and the general condition in which the line is maintained, and of that of the rolling stock.

Mr. Price Williams found that good iron rails bore from 12,000,000 to 15,000,000 tons of moderate fast traffic, and 38,000,000 tons slow traffic; while Bessemer rails bore 95,000,000 tons of slow traffic, without being worn out on even the single face. At Crew Station, England, Bessemer steel rails have borne 52,000,000 tons of traffic, with a wear of only 5-16 in.

Strength of Iron and Steel Rails.

Mr. Kirkaldy found that iron rails, supported on bearings 5 feet apart, bore 36,000 lbs. to 50,000 lbs., applied at the centre; steel rails not less than 56,000 lbs., and the tensile strength of steel rails 94,000 lbs. per square inch.

To Resist Impact, or Force of a Blow.

2 steel rails and 2 iron rails were keyed in chairs 4 feet apart, and weight of 560 lbs. let fall on them.

A fall of	4	feet	produced	no set	in	1st	steel rail.
"	10	"	"	1 in.	"	1st	"
"	20	"	"	2¼ in.	"	1st	"
"	20	"	"	1 in.	"	2d	"
"	26	"	"	1¼ in.	"	2d	"

Could not break steel rails with this weight; iron rails, 10 per cent. heavier, broke.

1st rail, with fall of 6 feet, same weight.
2d " " " 8 " "

STEEL AND IRON RAILS, AND MAINTENANCE OF PERMANENT WAY.

Compiled from "Engineering"—R. Price Williams, Esq., on Maintenance and Renewal of Permanent Way, and Observations on Same at the Institution of Civil Engineers, March 13, 1866, and Manufacture and Wear of Rails (C. P. Standberg, Esq., Assoc. Inst. C. E.)

It is well known that the condition of the permanent way has not kept pace with the demands upon it, from high speed and heavy and increasing traffic, comparing most unfavorably with the marked progress of other branches of railway engineering, while the weight of the locomotive has quadrupled in thirty years, from better workmanship, the operating expenses have decreased, during the past fourteen, while during the same period, the maintenance of way expenses has increased 200 per cent.

Experience shows that it is not so much by any ingenious or scientific distribution of materials employed, but by a more liberal use of a better and more durable material, in the form of rails, that economy will be effected; that, for high speeds and heavy traffic, an elastic road-bed, obtained by the employment of timber, is unavoidable.

The life of iron rails of best quality has been found to be 35,000,000 tons over a double line, or 17,000,000 over each single rail; and many from the best makers stand only 5,500,000 to 15,000,000 tons, the greatest wear being in cuttings and tunnels where there is the least elasticity. The average life of an iron rail being 15,000,000 tons, or equal to 100,000 trains of 150 tons each, independent of the length of time of the traffic, the wear may be estimated as the 1-100,000 part of the value of the rail each time a train goes over it; and if the value of a mile of iron rails be taken at $5,000, the wear would be 5 cents per train mile.

EXPERIMENTS ON VARIOUS KINDS OF IRON RAILS.

London and Northwestern Railway.

Mark of Rail.	Crushed. Tons.	Worn Out. Tons.	Mark of Rail.	Crushed. Tons.	Worn Out. Tons.
T	3,180,000	5,060,000	E	6,900,000	8,970,000
Y	4,140,000	5,290,000	N	3,220,000	3,520,000
H	3,220,000	5,060,000			

A table calculated from the above showed that above rails would be crushed in 6 years, and worn out in 9 years, by annual wear of 3,000 trains, of an engine weighing 30 tons, and 20 wagons of 10 tons each, or gross load of 230 tons. Trial rails, pattern E, heavier section, bore 276 millions, at speed of one mile per hour; at points where action of the brakes and switching was continued, wear was 102 million tons, at speed of one mile per hour. *To ascertain life of an iron rail, knowing the load which passes over the line and speed, multiply one into the other, the product divided by 220, quotient equal life of rails, in years.*

On the Great Northern Railway, at Barnet, the life of an iron rail was 5 years, with 13,484,661 tons of fast trains, and 38,303,028 tons slow traffic. Steel rails were only half worn out with 95,-577,240 tons traffic. As the life of an iron rail is but the 1-6th of a steel rail, it must follow that a great excess of mechanical work, represented in destruction of the iron rails by the rolling stock, must ensue. Locomotive power depending mainly on the resistance to traction (due to the deflection of track and abrasion), costs 25 cents to 31 cents per train mile, and anything which will reduce this by 1-5th or 1-6th, will soon effect a saving equal to the whole cost of the rails.

On falling gradients, with the traffic, the wear is greatest, owing to the momentum acquired; on a falling gradient of 1 in 130, a mixed traffic of 62,399 trains, gross tonnage 12,451,784 tons, wore out the best samples of iron rails in 7¼ years; on a level, with a heavy all one way traffic, same description of rails required 203,122 trains, and 38,803,128 tons, to wear them out in 7¼ years.

The destructive effects of high speed, with the same engine and everything similar, were such that the same rail required more than three times the traffic to wear them out at the lower speeds, and for equal quantities of traffic the wear of the rail is in the ratio of the square of the velocity (the matter in front compressed by the weight of the wheel is in proportion to the shortness of the time of passage, the resistance being as the square of the velocity).

On mineral roads, with heavy up and down grades, with diminished speed up grade, and accelerated speed down grade,

the wear and tear is considerably greater than if the same space is traversed at a uniform speed equal to the average speed.

The wear of a rail placed upon a chair upon tie, was similar to the effect of pounding a rail upon an anvil. the end flattens into a fan shape, while, if suspended, being sustained by fish plates, the hammering action of the train, being over a void, falls harmless on the ends of the rail.

DURATION OF IRON RAILS ON DESCENDING GRADIENTS,

Gt. N. R. R., between Hatfield and London, and on similar Ascending Gradient between 63d and 66th Miles.

	TRAFFIC OVER GRADIENT.	
	No. of Trains.	Tonnage.
GRADIENT FALLING 1 IN 200:		
Rails relaid Dec., 1857.		
" taken up Dec., 1860 = 3 yrs.	57,536	11,760,926
" relaid Dec, 1863 = 3 yrs.	65,529	13,484,661
" relaid Dec., 1857.		
" taken up June, 1860=2½ yrs.	47,445	9,679,078
" relaid April, 1863 = 2¾ yrs.	58,851	12,116,382
GRADIENT RISING 1 IN 200:		
Rails relaid Sept., 1860; sound Jan. 1, 1866 = 6 yrs.....	119,455	24,702,861

That on the London and Northwestern Railway, in 1847, miles MAINTAINED were 378½, at a cost of £240 per mile per annum, the cost of RENEWALS being £38 per mile per annum, increasing rapidly until 1851, when renewals reached £101 per mile per annum, at which time 1-7th of the whole double mileage maintained in 1847, or 94½ miles of single track, had been entirely renewed since 1847; in next five years (1852 to 1856, inclusive) cost of renewals had increased to £200 per mile per annum, or to a total sum equal to the cost of 450 miles of single line, or two-thirds of the whole double mileage of 1847 (378½ miles) renewed in ten years. In following five years (1857 to 1861) cost of renewals per mile per annum was £200, or equal to cost of 428 more miles of single track; from December, 1862, to

June, 1865—3½ years—cost of renewal averaged £151 per mile per annum, representing 389 more miles of single line, or in 19 years a grand total of £1,906,858 expended in *renewals of one way alone*, and representing 1,363 miles, or almost half the whole mileage maintained in 1865. Average annual expenditure for renewals since 1847 was £103,074, representing 73 miles of single way of the main line broken up and entirely replaced annually during that period, chiefly in places where the traffic was heaviest, and the facilities of doing the repairs the least, and danger of accident the greatest. The average cost of renewals per mile per annum, during a period of years, was, on following roads:

			Per mile per annum.
1. London and Northwestern R'y.	Average of	18½ yrs	£145
2. Northeastern Railway.....	"	14 "	83
3. Midland Railway.....	"	17½ "	84
4. London and Southwestern R'y.	"	11 "	72
5. Great Northern Railway.....	"	9½ "	110
6. Lancashire and Yorkshire R'y.	"	16½ "	156
7. Southeastern Railway.....	"	15½ "	102
8. London, Brighton, & S. C. R'y.	"	12½ "	94
9. Manchester, Sheffield, and Lincolnshire Railway.....	"	9 "	49

That on the above roads—

The total miles maintained in 1847, were.....	1,551
Increase of mileage, June, 1847, to June, 1864.....	= 3,330
Total mileage maintained June, 1864.....	= 4,881
Amount expended in renewals, June, 1848, to June, 1364.....	= £5,220,399
Estimated number of single miles renewed, June, 1847, to June, 1864.....	= 3,729
Average per cent. of miles renewed.....	38

Lamination of Iron Rails.

Iron rails, from being rolled from piles of iron, may be compared to a bundle of rods welded together, the upper surface or slab being of a very hard and crystalline iron to stand the wear of the wheels, and the bottom of a more elastic and fibrous iron, to prevent breakage from the passing load. On examination of

Ramapo Wheel and Foundry Co.

the particles of iron which splinter or laminate from the head of rails, it will generally be found that some foreign particle, such as rust, dirt, cinder, or a drop of melted fire-brick, has prevented a true weld between the slabs forming the rail, and that in many cases they are cemented together by cinder. By the introduction of steel for rails, ingots of sufficient size can be made to make the rail from one piece, which will obviate the lamination so frequently found in iron rails.

RAILS REMOVED FROM TRACK, AND COST OF RENEWING IRON,

On the Philadelphia and Reading R. R., per ton carried.

Years.	Tonnage.	No. of Bars removed from Tracks.	In proportion to Tonnage.	Cost of Renewing Iron.	Cost pr Ton, in Cents.
1850	1,764,680	4,219	1 bar for 413	$12,115 07	0.69
1851	2,145,132	5,932	1 " 361	25,825 25	1.21
1852	2,122,171	7,327	1 " 303	24,954 24	1.17
1853	2,079,197	8,032	1 " 233	35,546 59	171
1854	2,582,563	11,112	1 " 232	67,176 08	260
1855	2,909,667	29,965	1 " 113	160,138 64	560
1856	2,815,760	31,036	1 " 91	204,502 51	726
1857	2,326,706	23,568	1 " 98	154,686 50	664
1858	2,126,181	19,761	1 " 108	128,629 15	649
1859	2,405,414	11,337	1 " 147	103,334 65	429
1860	2,819,898	19,291	1 " 146	114,420 90	406
1861	2,348,906	17,579	1 " 133	85,957 75	365
	Tons carried 100 Miles.				
1862	2,443,377	11,636	1 " 210	62,621 50	256
1863	3,404,269	15,339	1 " 222	90,832 14	267
1864	3,677,747	27,209	1 " 135	214,602 86	583
1865	3,953,906	26,168	1 " 151	196,139 52	496
1866	4,812,328	34,223	1 " 141	251,787 18	523
1867	4,533,275	34,375	1 " 132	255,154 78	562

Comparative Cost of Iron and Steel Rails.

Data from American Railway Times.

Iron rails, taken as worth $90 per ton; re-rolled and re-laid once in five years, at a cost of $40 per ton, and worth at end of 20 years $50 per ton for old iron; or steel rails, at $160 per ton, to last 20 years, and be worth old steel (o), at end of that time.

The iron rails first year cost $90 per ton; add $3 00 for laying, is $93 00; at the end of each five years, add cost of re-rolling, $40 00; freight, $4 00; relaying, $3 00; incidental waste of ties and spikes, $2 00; or, say, in all, $49 00 per ton, with interest at 6 per cent. added from year to year. The steel rails cost $160 per ton; add for laying, $3 00; or, say $163; and add this to the interest on the cost, as before, and we have the following comparative cost of the two metals at the end of each year:

	Steel.	Iron.		Steel.	Iron.
Beginning.....	$163 00	$93 00	End of 11th yr.	$309 35	$300 30
End of 1st yr..	172 78	98 58	" 12th yr.	327 91	318 31
" 2d yr..	183 14	104 49	" 13th yr.	347 58	337 40
" 3d yr..	194 12	110 75	" 14th yr.	368 43	357 64
" 4th yr..	205 76	117 39	" 15th yr.	390 53	379 09
" 5th yr..	218 10	124 43	" 16th yr.	413 96	453 77
" 6th yr..	231 18	183 83	" 17th yr	438 79	480 19
" 7th yr..	245 05	194 85	" 18th yr.	465 11	509 84
" 8th yr..	259 75	208 54	" 19th yr.	493 01	540 48
" 9th yr..	275 33	221 05	" 20th yr.	522 59	572 85
" 10th yr..	291 84	234 31			

If the old iron is worth $50, and the steel nothing, at the end of 20 years the account would be about balanced; but if the compound process be carried on for 40 years, or even 30 years, the result in favor of steel would be marked. One steel rail will outwear twenty iron rails, with the same traffic, in place of four iron, as above.

If steel rails can be made one-seventh lighter than iron rails, the saving on 100 miles of road would be $224,000. This sum, with interest compounded from year to year, for 20 years, would be $718,405 82.

STATEMENT showing the Number and Gross Weight of Trains *From* 1858 *to* 1865, *with the Average Life of Experimental*

Gradient.	Locality.	No. of Rails Laid, Aug., 1858.	25 per Cent. Iron.		
			Duration of Rails.	Number of Trains.	Gross Tonnage.
	Beale's Boiler Plate.		Years.		
Falling 1 in 50	Hunt's Bank	20	..	....	.....
Level	Bolton	8	..	...	.....
Falling 1 in 100	Wigan	10	5	71,614	13,911,951
Rising 1 in 88	Liverpool	8	2½	34,109	3,547,310
Level	Blackburn	8	3½	43,799	8,193,635
"	Accrington	8	2½	18,766	3,507,340
"	Bury Tunnel	2	..	...	.....
Falling 1 in 130	Ramsbottom Viaduct	6	..	....	.....
	Lowmoor.				
Falling 1 in 50	Hunt's Bank	20	..	....	.....
Level	Bolton	2	3½	89,059	16,348,556
Falling 1 in 100	Wigan	20	7¼	103,182	19,488,540
Rising 1 in 88	Liverpool	8	5	72,890	7,580,560
Rising 1 in 200	Preston Curve	6	2½	17,915	3,278,421
Level	Bury Tunnel	8	3½	28,043	5,445,974

passing over certain Portions of the Lancashire and Yorkshire Railway, *Rails at Various Stations.*—(Price Williams.)

50 per Cent. Iron.			75 per Cent. Iron.			All Worn Out.			Percentage Serviceable Dec. 1, 1865.
Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	
Years.			Years.			Years.			
7¼	178,424	25,447,601	..	....	.....	.	....	.....	50 p. c.
..	....	.....	3½	89,059	16,348,556	4¼	104,542	19,166,356	Nil.
6 1-6	86,940	16,680,225	7¼	103,182	19,488,540	..	....	.....	25 p. c.
3½	49,530	5,151,120	4¼	58,655	6,100,120	6 1-6	94,608	9,839,180	Nil.
...	....	.....	..	....	.....	7¼	97,545	18,503,379	Nil.
3½	25,518	4,766,682	5	34,309	6,278,116	7¼	50,703	9,305,594	Nil.
2½	18,553	3,450,245	5	41,001	8,078,354	7¼	62,399	12,451,784	Nil.
2½	18,553	3,450,245	3½	28,043	5,445,974	4¼	33,975	6,665,074	Nil.
6 1-6	144,235	20,261,605	7¼	178,424	25,447,601	..	....	.....	25 p. c.
..	....	. ....	5	126,411	23,324,679	6 1-6	165,283	31,251,932	Nil.
..	....	.....	..	....	.....	..	....	.....	75 p. c.
6 1-6	94,608	9,839,180	..	....	.....	7¼	116,872	12,154,740	Nil.
..	....	.....	3½	24,850	4,586,856	5	34,431	6,311,024	Nil.
..	....	.....	7¼	62,399	12,451,784	..	....	.....	25 p. c.

Lamapo Wheel and Foundry Co.

Statement of Wear of Rails over certain Portions of

Gradient.	Locality.	No. of Rails laid, Aug., 1858.	25 per Cent. Iron. Duration of Rails.	Number of Trains.	Gross Tonnage.
	Mersey Steel Co. Solid Steel.		Years.		
Falling 1 in 50	Hunt's Bank	28	5	110,081	15,440,259
Level	Blue Pits	14	2½	60,437	12,041,870
"	Bolton	8	3½	89,059	16,348,556
Rising 1 in 88	Liverpool	68	6 1-6	94,608	9,839,180
Level	Accrington	20	5	34,309	6,278,116
Falling 1 in 130	Ramsbottom Viaduct	8	2½	18,553	3,450,245
Level	Bury Tunnel	2	7¼	62,399	12,451,784
	Thorneycroft's Charcoal Top.				
Falling 1 in 50	Hunt's Bank	78	6 1-6	144,235	20,261,605
Level	Blue Pits	46	3½	83,797	16,654,466
"	Bolton	8	2½	62,323	11,369,773
Rising 1 in 150	Miles Plating	10	..	....	.....
Falling 1 in 100	Wigan	10	7¼	103,182	19,488,540
Rising 1 in 88	Liverpool	10	6 1-6	94,608	9,839,180
Rising 1 in 200	Preston Curve	16	3½	24,850	4,586,856
Level	Bury Tunnel	8	2½	18,553	3,450,245

the Lancashire and Yorkshire Railway—Continued.

50 per Cent. Iron.			75 per Cent. Iron.			All Worn Out.			Percentage Serviceable Dec. 1, 1865.
Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	
Years.			Years.			Years.			
7¼	178,424	25,447,601	..	....	.....	..	....	.....	50 p. c.
3½	83,797	16,654,460	7¼	173,907	35,052,063	..	....	.....	25 p. c.
5	126,411	23,324,679	..	....	.....	7¼	203,122	38,803,128	Nil.
..	....	.....	..	....	.....	7¼	116,872	12,154,740	Nil.
7¼	50,703	9,305,594	..	.....	.....	..	....	.....	50 p. c.
3½	28,043	5.445,974	7¼	62,399	12,451,784	..	....	.....	25 p. c.
..	....	.....	..	....	.....	..	....	.....	75 p. c.
7¼	178,424	25,447,601	..	....	.....	..	....	.....	50 p. c.
6 1-6	146,912	29,431,596	7¼	173,907	35,052,063	..	....	.....	25 p. c.
3½	89 059	16,348,556	4¼	104,542	19,166,356	6 1-6	165,283	31,251,932	Nil.
3½	95,689	13,404,498	4¼	114,396	15,952,198	5	141,741	19,799,789	Nil.
..	....	.....	..	.....	.....	..	....	.....	75 p. c.
..	....	.....	..	....	.....	7¼	116,872	12,154,740	Nil.
5	34,431	6,311,024	7¼	49,305	8,929,397	..	....	.....	25 p. c.
3½	28,043	5.455,974	4½	33,975	6,665,074	5	41,001	8,078,354	Nil.

Ramapo Wheel and Foundry Co.

Statement of Wear of Rails over certain Portions of

Gradient.	Locality.	No. of Rails Laid, Aug., 1858.	25 per Cent. Iron.		
			Duration of Rails.	Number of Trains.	Gross Tonnage.
	Beale's (Dodd's Steeled).		Years.		
Falling 1 in 50	Hunt's Bank	20	4¼	89,820	12,484,945
Level	Bolton	8	..	....	.....
Falling 1 in 100	Wigan	10	4 1-6	86,940	16,680,225
Rising 1 in 88	Liverpool	10	4¼	58,655	6,100,120
Level	Blackburn	8	..	....	.....
"	Accrington	8	.	....	.....
Falling 1 in 130	Ramsbottom Viaduct	8	..	....	.....
	Crewe.				
Falling 1 in 50	Hunt's Bank	58	..	....	.....
Level	Bolton	8	..	....	.....
Falling 1 in 100	Wigan	10	3½	52,178	10,349,806
Rising 1 in 88	Liverpool	10	..	....	.....
Level	Blackburn	8	4¼	52,924	10,008,369
"	Accrington	8	..	....	.....
Falling 1 in 130	Ramsbottom Viaduct	8	2½	18,553	3,450,245

the Lancashire and Yorkshire Railway—Continued.

50 per Cent. Iron.			75 per Cent. Iron.			All Worn Out.			Percentage Serviceable Dec. 1, 1865.
Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	Duration of Rails.	Number of Trains.	Gross Tonnage.	
Years.			Years.			Years.			
5	110,081	15,440,259	7¼	178,424	25,447,601	..	....	.....	25 p. c.
2½	62,323	11,369,773	3½	18,059	16,348,556	4¼	104,542	19,166,356	Nil.
7¼	103,182	19,488,540	..	....	.....	..	....	.....	50 p. c.
..	....	.....	6 1-6	94,608	9,839,180	7¼	116,872	12,154,740	Nil.
2½	29,199	5,335,228	..	....	.....	6 1-6	79,387	15,101,716	Nil.
2½	18,766	3,507,340	3½	25,518	4,766,682	4¼	29,397	5,433,491	Nil.
2½	18,553	3,450,245	..	....	.....	3½	28,043	5,445,974	Nil.
3½	74,763	10,392,126	4¼	89,820	12,484,945	5	110,081	15,440,259	Nil.
2½	62,323	11,369,773	3½	89,059	16,348,556	5	126,411	23,324,679	Nil.
5	71,614	13,911,951	..	....	.....	6 1-6	86,940	16,680,225	Nil.
2½	34,109	3,547,310	..	....	.....	4¼	58,655	6,100,120	Nil.
..	....	.....	6 1-6	79,387	15,101,716	7¼	97,545	18,503,379	Nil.
3¼	25,518	4,766,682	6 1-6	42,461	7,768,290	7¼	50,703	9,305,594	Nil.
..	....	.....	..	....	.....	3½	28,043	5,445,974	Nil.

Ramapo Wheel and Foundry Co.

Steel Rails.

The prejudice which for a long time existed against the use of steel for rails, shafts, and severely strained structures in general, was probably due to the very varying results given by the early experiments on the strength of steel, no material being more powerfully affected by different methods of treatment. A specimen of cast-steel highly heated and cooled in oil, bore a tensile strain of 96 tons per square inch, while a similar piece, cooled in water, failed with 40 tons, and another piece, slowly cooled in ashes, failed with 54 tons per square inch.

Increased hardness brings with it the advantage of increased resistance to *steady* tensile strain, but only at the expense of lessening the power of resisting a blow. This latter resistance will be represented by the work done in fracturing the bar, which is approximately the breaking weight by one-half the ultimate extension. The work done in fracturing a specimen of steel when hardened, was in the proportion of 96 tons $\times$ 3.3 per cent., equal to 3.16, while same steel in soft state, the work done was in proportion to 54 tons $\times$ 7 per cent. = 3.78, thus showing 20 per cent. increase in power of resisting, although the ultimate strength of the material was 44 per cent. less than before.

In the manufacture of steel rails, the proper mean must be sought. To resist the effects of abrasion from ordinary traffic or effects of sliding the wheels upon its upper surface, they can not be too hard, while to resist rough handling and effects of drilling and punching, they can not be too soft.

Rails with a proper degree of toughness should bear a direct tensile resistance of 35 tons per square inch.

The proper test of a rail is by a gradually increasing bending stress to the centre of a rail, resting upon bearings about 5 feet apart, the deflection and set being noted after each successive increment of stress; and to know the real value of the material, the *work done* in producing fracture must be known, which in the steel rail will always be equal to the product of the ultimate tensile resistance by one-half the ultimate extension, the toughest and best materials always giving the highest results.

The tensile strength of Bessemer steel rails and plates of the same material, give the same results, the section of the rail not materially affecting the resistance per unit of area.

TENSILE STRENGTH OF BESSEMER PLATES.

(*G. Berkley, Esq., C. E.*

		Elongation commenced. Tons per sq. in.	Broke. Tons per sq. in.
Section = .625 × 1.55 = .813 sq. in.		24½	46
Section = .59 × 1.68 = .96 "		20⅓	43
Section = 54 × .55 = .73 "		20½	44.7
Section = .58 × 1.55 = .899 "		22½	44.5

Elongation begins at average of 22 tons per square inch.

Pieces broke at average of 44½ tons per square inch.

Same plates, tested by Mr. Samuda, gave 43½ tons per square inch.

Average of 4 experiments on steel in Holland, 42 tons per square inch.

Average of 37 experiments at Chatham Dock Yard, 42 tons per square inch.

Bessemer steel plates have a tensile strength about double that of good iron plates, Bessemer averaging from 43 tons to 46 tons—mean 44½ tons—elastic resistance beginning on average at 22 tons per square inch. Lowmoor and Bowling iron have an average tensile strength of 33 tons per square inch, mean ultimate elongation being 22.8 per cent.

Average of iron plates, by Kirkaldy, gave 21¾ tons per square inch ultimate resistance to tension, and 7 per cent. ultimate elongation. The work of rupturing the plates would, in terms of the average iron plate, be 2.35 for the best make of iron, and 4.9 for cast-steel plates.

Average Results—Bessemer Steel Rails.

Pieces from web—3 experiments—breaking weight = 41½ tons.
" head—2 " " " = 43½ "

The power of the lower web of a Bessemer steel rail to resist tension being as in preceding tables, the power to resist compression of the upper web was found to be, in cylinders of Bes-

semer steel, 0.755 of an inch diameter × 1 inch in height—as follows—showing permanent set taking place with 18 tons per square inch:

Compression of Steel.

Experiments with Steel Cylinders—Diameter 0.755.

Weight on		Length.	Compression.
Lbs.	Tons.	Inches.	Inches.
.....	.....	1.033	....
5.000	2.232	1.033	...
10.000	4.464	1.032	.001
15.000	6.696	1.032	.001
18.000	8.035	1.032	.001
20.000	8.928	1.029	.004
22.500	10.044	1.02	.013
25.000	11.16	1.012	.021
30.000	13.392	.996	.037
40.000	17.857	.944	.089
50.000	22.321	.87	.163
60.000	26.785	.783	.25
80.000	35.714	.572	.461
100.000	44.642	.563	.47

Ultimate diameter 1.09

3d experiment gave ultimate diameter..... 1.062
4th " " " " 1.086
5th " " " " 1.077
6th " " " " 1.09
7th " " " " 1.083
8th " " " " 1.08
9th " " " " 1.05
10th " " " " 1.06

Deflection and Permanent Set of Rails.

Experiments with Iron Rails.

Weight of rail, 68 lbs.

Makers.	20 Tons.		30 Tons.	
	Def.	Per't Set.	Def.	Per't Set.
	Ins.	Ins.	Ins.	Ins.
*Ebbw Vale Co.	.72	.58	2.13	1.96
†Bucklow, Vaughn & Co.	.67	.56	1.81	1.67
‡Patent Shaft Co.	.52	.37	2.71	2.58
3)	1.91	1.51	6.65	6.21
Average	.63	.50	2.21	2.07

* 82 experiments; † 80 experiments; ‡ 365 experiments.

Experiments with Steel Rails.

Weight of rail 68 lbs.

Makers.	20 Tons.		30 Tons.		Def.	Per't Set.	Greatest Weight.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Tons.
*J. Brown & Co.	.32	15	1.72	1.20	3.87	3.45	38.7

* 45 experiments; greatest strain rail bore = 50½ tons.

Average of 30 Experiments on Iron Rails—85 lbs. to the Yard.

Makers.	25 Tons.		30 Tons.	
Pat. Shaft and Ebbw Vale Co.	Ins.	Ins.	Ins.	Ins.
Average	.60	.45	2.81	1.57

Average of 18 *Experiments on Steel Rails*—85 *lbs. to the Yard.*

Makers.	25 Tons.		35 Tons.		Def.	Per't Set.	Greatest Weight.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Tons.
J. Brown & Co.	.26	.10	1.03	.79	3.82	3.45	45.

Greatest strain rail bore = 64.5 tons.

68-lb. Section.

Def. of S. R., with 20 tons, was to def. of I. R., with 20 tons, as 1 is to 2.
Per't Set S. R., " 20 " " per't set I. R., " 20 " " 1 " 3.3
Def. of S. R., " 30 " " def. of I. R., " 30 " " 1 " 1.28
Per't Set S. R., " 30 " " per't set I. R., " 30 " " 1 " 1.72

86-lb. Section.

Def. of S. R., with 25 tons, was to def. of I. R., with 20 tons, as 1 is to 1.23
Per't Set S. R., " 25 " " per't set I. R., " 25 " " 1 " 1.45
Def. of S. R., " 35 " " def. of I. R., " 35 " " 1 " 1.7
Per't Set S. R., " 35 " " per't set I. R., " 35 " " 1 " 1.9

Steel rail by Messrs. Cammell & Co.—flat-bottom flange rail, 69 lbs. to the yard, with blow from 1 ton ram falling 15 feet—was deflected 5⅜ inches, expanding the upper flange 3-16 inches, narrowing the bottom flange ⅜ inches. By hydraulic test, same rail gave, with load:

	Deflection.	Per't Set.
15 tons	0.14	Nil.
20 "	0.57	0.4

Combined Steel and Iron Rail.

It was found, on the Cologne and Minden Railway, that iron rails, 56 lbs. per yard, were worn out in 2 years. Rails of same weight, with ⅜ steel face, or 1-12 per cent. of the whole rail, wore out in 11 years, with 30,000,000 tons traffic, but to prevent breakage, the steel section had to be at least 47½ per cent. of the whole section.

The great difficulty has been to produce a reliable weld between the steel and the wrought-iron, but this trouble is rapidly being obviated; the method adopted at Crewe is to place a bar of soft puddled iron between the steel of the top and the old rails used in the lower part of the rail, and, as a further protection, the steel for the head is rolled in the form of a channel bar,

with ribs in the recessed portion so as to fold around and embrace, as it were, the head of the rail. The cost of iron and steel rail is between that of all steel and iron, and has the advantage of rendering old iron rails available for remanufacture. While it is stated that the saving in expense is not equal to the difference between that of an all iron or all steel, the latter can be made equal to all the requirements of traffic, and when worn out worked over. The combined steel and iron, when reworked, can not be forged or rerolled with effect, because the properties of one part of the rail essentially differ from the other.

MAKERS AND DESCRIPTION OF RAILS TESTED BY D. KIRKALDY, ESQ., LONDON, 1866.

(*See Results of Experiments on following pages.*)

	Description.	Double-Headed Rails.		
		Width.	Height.	Thickness of Web.
STEEL.	Crewe, 1866 (new) . . . . . A	2.68	5.40	.75
	J. Brown & Co. (new) . . . . . B	2.60	5.22	.75
	Bess. Chalk Farm rail (slightly w'rn) C	2.60	5.20	.74
	Cammell & Co. (new) . . . . . D	2.50	5.02	.73
	Bess. Chalk Farm rail (much worn) E	2.60	5.00	.6
	S. Fox & Co, 1865 (new) . . . . . F	2.55	5.10	.70
	S. Fox & Co., 1864 (new) . . . . . G	2.45	5.00	.73
S. & I.	Crewe, 1866 (new), steel face up . . . H	2.75	5.40	.81
	S. Fox & Co. (new), steel face down . J	2.55	5.10	.70
	S. Fox & Co. (new), steel face up . . K	2.55	5.10	.70
IRON.	Crewe, 1866 (new) L	2.75	5.40	.82
	Ebbw New, 1865 (new) . . . . . M	2.65	5.25	.78
	Crewe, 1866 (new) . . . . . N	2.72	5.40	.82
	Rail from Chalk Farm (much worn) . O	2.60	5.20	.70
	Ebbw Vale (new) . . . . . P	2.50	5.04	.68
	Flange rail (new) . . . . . Q	2.32	4.22	. . .
	Bridge rail (new) . . . . . R	2.52	3.40	5.90
	Bridge rail (new) . . . . . S	2.25	2.70	6.00
	Bridge rail (new) . . . . . T	2.10	2.70	5.70

Results of Experiments to Ascertain Resistance to Deflection and Set,

Forms and Size—Distance between Supports, 60 inches—made

Description.			Area in Sq. Ins.	Ultimate Total, in Lbs.	Strain per Sq. Inch, in Lbs.		3,000 Lbs.	Set.	5,000 Lbs.	Set.	9,000 Lbs.	Set.	13,000 Lbs.	Set.
Steel.		A	7.67	80,170	10,453	*	.002	..	.013	..	.042	.002	.074	.012
		B	7.72	79,368	10,281	†	.012	..	.031	..	.063	.010	.100	.017
		C	7.25	74,926	10,334	‡	.111	..	.022	..	.055	.008	.091	.012
		D	7.11	71,53	10,061	*	.008	..	.028	..	.064	.008	.101	.011
		E	6.55	69,93	10,677	‡	.000	..	.009	..	.045	.002	.078	.015
		F	7.53	62,224	8,263	‡	.009	..	.019	..	.055	.003	.090	.011
		G	6.75	57,400	8,504	*	.007	..	.025	..	.060	.014	.095	.023
S. I.		H	8.11	61,952	7,639	*	.005	..	.022	..	.059	.021	.092	.032
		J	7.48	57,232	7,651	§	.000	..	.008	..	.043	.	.074	..
		K	7.48	51,268	6,854	‖	.004	..	.016	..	.052	..	.094	..
Iron.	Double-Headed.	L	8.25	51,520	6,245	†	.015	..	.027	..	.058	.011	.090	.015
		M	8.17	50,112	6,134	*	.008	..	.025	..	.062	..	.112	..
		N	8.29	47,280	5,703	‡	.012	..	.030	..	.062	.010	.098	.015
		O	7.02	43,480	6,193	‡	.007	..	.018	..	.051	013	.081	.019
		P	6.83	35,720	5,230	¶	.018	..	.038	..	.082	..	.125	..
		Q	5.89	28,948	4,915	†	.023	..	.055	.009	.119	.028	.182	..
		R	7.75	18,400	2,374	**	.041	..	.086	..	.156	..	.268	..
		S	5.57	10,917	1,960	**	088	.017	.186	.032	.738	.388	..	..
		T	4.18	8,235	1,970	**	.094	..	.237	.063	..	..	..	..

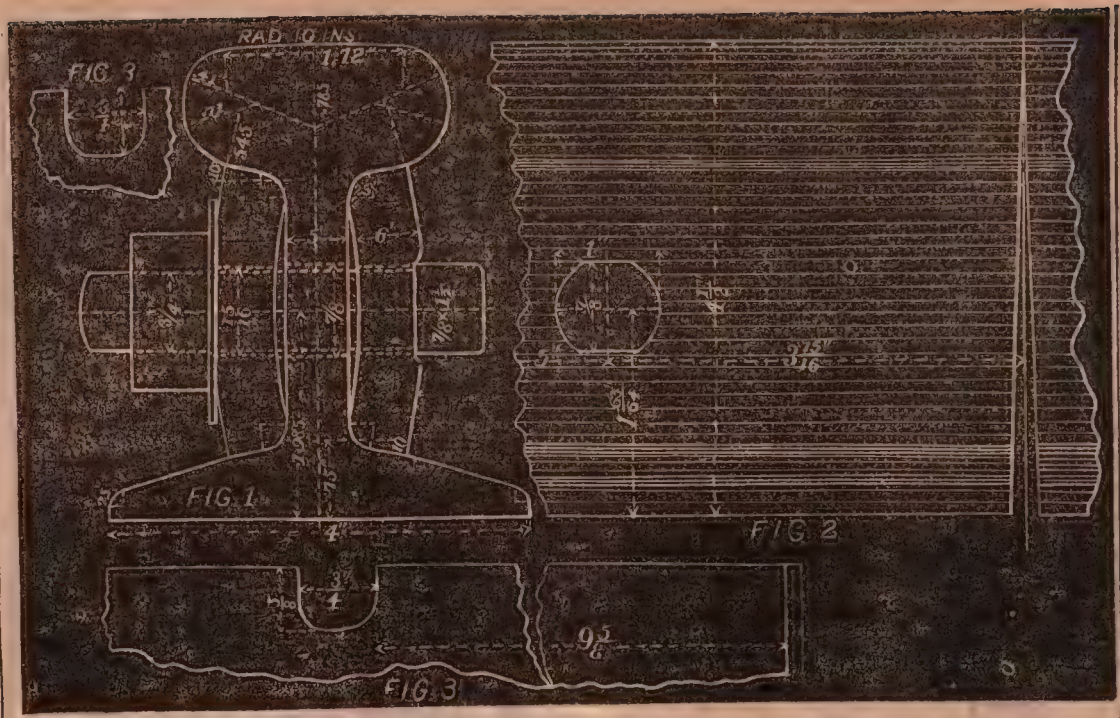
Remarks.—* Snapped; † C. and Canted; ‡ Canted; § Steel Cracked, Iron entire;

under a Gradually Increasing Bending Strain, of Various Materials, *by David Kirkaldy, Esq., London,* 1866.—(PRICE WILLIAMS.)

20,000 Lbs.	Set.	26,000 Lbs.	Set.	30,000 Lbs	Set.	36,000 Lbs.	et.	40,000 Lbs.	Set.	50,000 Lbs.	Set.	60,000 Lbs.	Set.	70,000 Lbs.	78,000 Lbs.	80,000 Lbs.
.125	.022	.170	.032	.202	.043	.252	.055	.307	.085	1.13	858	2.54	..	4.54	6.44	7.15
.153	.035	.202	.051	.231	.063	.285	..	.375	.21:	1.38	..	2.98	..	5.26	7.64	..
.148	.022	.192	..	.223	.041	.280	..	.336	072	.778	452	1.75	..	3.57	..	..
.165	.020	.218	032	.257	.043	.322	.051	.388	.072	1.06	.622	2.15	1 64	3.64	..	..
.132	..	.189	.028	.229	.037	.302	.056	.418	.137	1.29	.928	2.74	2.2:	..	..	..
.145	.022	.198	.032	.235	.041	.950	742	1.83	..	4.69	..	8.14	..	..	..	..
.157	.030	.209	.035	.249	.041	.305	.047	.349	.051	.532	.128	..	..	..	..	..
158	.040	.212	.079	.298	.139	.752	..	.154	..	5.02	..	10.17	..	..	..	..
.138	..	.268	..	.654	.508	1.50	..	.256	..	6.42	..	..	..	..	..	..
.173	..	.462	.362	.840	..	2.61	..	4.30	..	10.25	..	..	..	..	..	..
.142	.028	.198	.046	.268	.092	.578	..	1.08	.889	4.25	..	..	..	..	..	..
.189	.070	.282	.108	.455	220	1.01	..	1.96	..	6.95	..	..	..	..	..	..
.164	.048	.238	069	.350	.172	.782	.548	1.37	1.04	..	..	..	..	..	..	..
.148	.030	.223	.046	.315	.105	.540	..	.875	.597	..	..	..	..	..	..	..
.250	..	.452	.283	.935	..	2.50	..	..	..	..	..	..	..	..	..	..
.425	.188	.235	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

‖ Steel entire, Iron torn; ¶ Torn; ** Cracked through bolt-holes, and then torn asunder.

Dunlop Tyres and Foundry Co.



STEEL RAIL—PENNSYLVANIA RAILROAD, 1868.

65 *Lbs. per Yard.*

FORM OF RAIL ADOPTED BY ERIE RAILWAY CO., 1868.

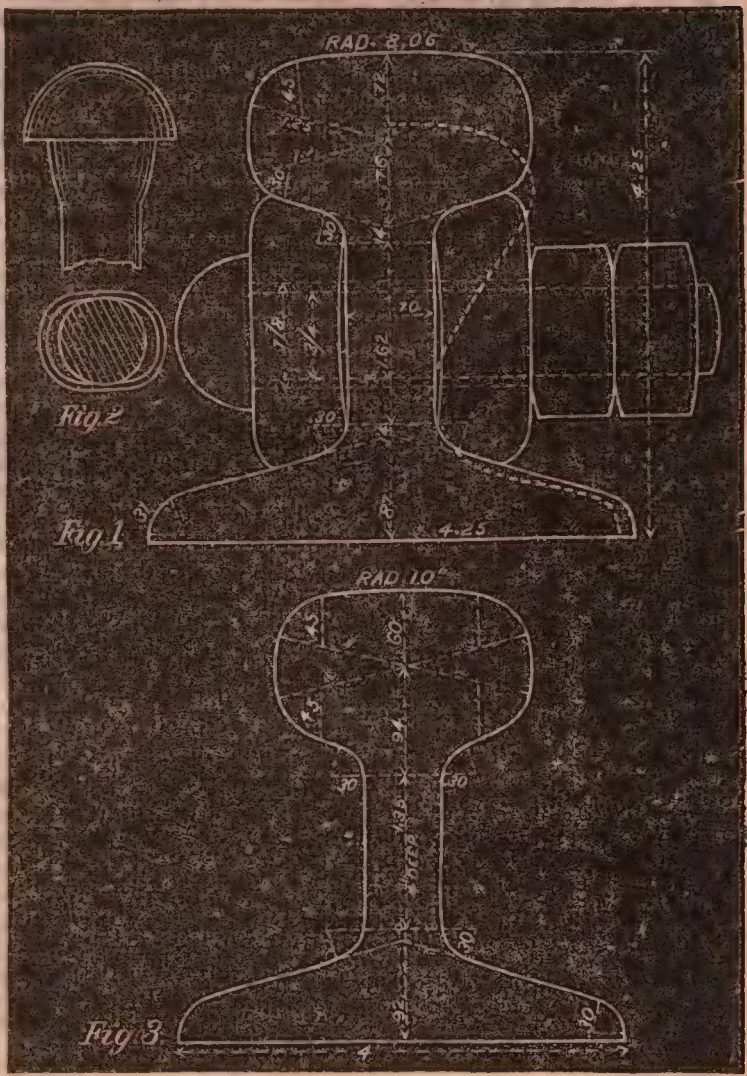


FIG. 1.—70 lb. per yard Iron Rail, with section of old pattern 56 lb. rail shown.

FIG. 2.—Bolt for Fish-plate.

FIG. 3.—Steel Rail, 65 lb. per yard. Proportion of Metal: Head = 0.45; Web = 0.14; Foot = 0.41; Total, 1.00.

Ramapo Wheel and Foundry Co.

Effect of Punching Rails.

The effect of punching steel rails is confirmed by results of punching steel and iron plates, in reducing their tensile resistance per square inch (page

From the elasticity of the steel about the punched hole being destroyed, at that point it will be giving away when at all other points it will be strained little, if any, beyond the elastic limit, and the deflection and "*fatigue*," under repeated strains, will be concentrated at the hole.

From experiments, the amount of the ultimate deflection of a steel rail, on 60-inch bearings, was, for a solid rail, 10.5; drilled rail, 2.4; punched rail, .35; the respective weights being 29.17 tons, 19.7 tons, and 13.4 tons. The work done in effecting rupture in each case would be proportional to the product of the weight by one-half the corresponding deflection. In foot tons the value would be, for solid rail, 12.76; drilled rail, 1.97; punched rail, .195; the drilled rail thus offering 10 times and the solid 65 times the resistance of the punched rail.

The ultimate deflection of a punched steel rail is precisely the same as of a cast-iron one of similar sections, the weight required to produce these deflections being in the ratio of 2½ to 1; the amount of deflection being so small—less than ⅜ inch—that imperfect packing of the sleepers might easily permit it; so, if the weight on a driving wheel of a locomotive were some 60 per cent. greater than it is at present, fracture frequently would occur, and a punched steel rail will be strained beyond the limits of elasticity by the passage of an ordinary train, if an intermediate sleeper sank 1-6th of an inch. There being a loss of 32 per cent. between a drilled and punched rail, a steel rail of direct tension of 36 tons, loss 32 per cent. = 24½ tons; value of a punched rail about equal to that of an iron rail, the average of which have tensile strength of 22 tons.

Effect of Strains and Changes of Temperature on Iron and Steel.

The results of a number of experiments in regard to repeated strains applied to iron and steel, made by M. Knut Styffe, the director of the Polytechnic College at Stockholm, coincide fully with the experiments given under "Fatigue of Metals," by M.

Stummer (see page 103), that repeated strains, exceeding the elastic limit, act in a similar manner upon a bar of iron or steel, as the repeated operations of hammering, rolling, or pressing, when in the cold state, viz., they raise the limit of elasticity, but they diminish the flexibility or softness of the metal. The opposite effect is due to the operation of annealing or heating and gradual cooling, and the result of such an annealing process is proportionate, to a certain extent, to the degree of heat applied. The addition of carbon to steel up to the limit of 1.2 per cent., increases the strength and hardness; above that proportion the strength commences to decrease with a further addition of carbon.

The tensile strength of iron and steel is not materially affected by change of temperature, being the same at temperatures down to 32° F. (below freezing point) as they are at the ordinary temperatures; between 212° F. and 392°, the strength of steel is the same as at ordinary temperatures; the strength of iron is greater with an increase of heat, being 20 per cent. stronger at 212° to 392° than at 15°. The *pliability* or *softness* of steel remains about the same in the cold and in the heat up to 392°; *softness* of iron, on the contrary, *decreases* as the temperature *increases*. In the heated state, steel keeps about the same limit of elasticity up to 252° F., while that of iron decreases about 10 per cent. Iron can sustain a *greater load in the cold* than at ordinary temperature, without showing any permanent set, the modulus of elasticity of both iron and steel decreasing with an increase of temperature.

Iron is more affected by changes of temperature than steel, and it was found by M. Styffe that great cold, instead of making iron and steel weak and brittle, seems to have the very opposite effect, breakage ensuing, particularly in railway practice, from secondary causes, such as the freezing and hardening of the ballast and wooden sleepers, the unequal contraction of parts shrunk or riveted upon others, and to the direct action of ice formed within the joints and crevices of iron structures exposed to the influences of the weather.

Expansion of Metals.

Metals expand by heat and contract by cold.

	Expansion per deg. Fah.	Expansion from 32° to 212°.
Iron	.0000067	.00122
Steel	.0000069	.00124
Copper	.0000090	.00171
Zinc	.0000160	.00294
Tin	.0000120	.00217

Almost all solid bodies expand equally for each degree between freezing and boiling, or from 32° to 212° F. A railway bar of 25 feet in length will, therefore, with an increase of 60° of temperature, become 25 x 60 x .0000067 = 25.01 feet in length or 25 feet ⅛ inch.

Ramapo Wheel and Foundry Co

Specification of the Mode of Re-Manufacturing Old Railroad Iron.

Data from Specifications of the Erie R. R. and Pennsylvania R. R.

1st—The old rails shall be piled in piles, and every piece shall be the whole length of the pile, and the pile so made shall be rolled into flats.

2d—All rails classed as 64 lbs. to 67 lbs., shall be rolled from a 9-inch rail pile, said pile to be made as follows:

3d—The said flats shall be put into a pile of proper size for a rail, each flat being of the full length of the pile, and of which flats, the bar forming TOP or HEAD of the rail shall be of NEW, GOOD, TOUGH, GRANULAR REWORKED IRON, such as will WELD WELL; to be 1¼ inches thick.

4th—The layers forming the CENTRAL PART or STEM of the rail, shall be of puddled or reworked iron, of a good quality, or of old rails (at the option of the manufacturer), rolled to a thickness of not over ⅞ inches, and of such width that the various layers will break joints, and what is known as a *staggered pile* formed.

5th.—The base of the pile from which the BOTTOM or FLANGE of the rail is made, shall be of good reworked fibrous iron—the under layer of which shall be of full width and length of pile, not less than 1⅞ inches thick. The pile shall be well and carefully heated, so as to insure a good weld.

6th.—The short pieces furnished by the railroad company, and all short pieces cut off by the rolling-mill, shall be piled by themselves, and rolled into a flat, which flat shall either be piled in the rail-pile, or used in making flanges of the rail. The railroad company shall have the right, from time to time, to direct in what part of said pile said flats so made of the pieces shall be placed; not more than two such flats shall be in any one pile.

7th.—The rails to be rolled to pattern furnished by railroad company; to be 25 feet long; not over ten per cent. shall be of shorter lengths, but not less than 18 feet; all rails to be undercut ⅛ inch; to be notched 2½ inches from each end, the notch to be ½ an inch deep and ⅞ inch long, or of such dimensions as railroad superintendent may direct.

8th.—It is mutually agreed, that the railroad company shall

not exact from the iron works rails classed as rerolled, to be of better material in the *central parts* and *base* of the pile than can be produced from the old iron furnished by said railroad.

9th.—Rails and process of manufacture shall be subject to inspection by such persons as the superintendent of the railroad shall select and appoint for that purpose.

PROCESS OF MANUFACTURE OF RAIL BLOOMS ADOPTED AT THE CWM AVON WORKS IN GLAMORGANSHIRE, WALES, is that of making unlaminated iron. The bloom being of unlaminated wrought iron, made directly from the refinery in the ordinary way, then run into another refinery—refining process being continued until it becomes wrought iron—it is then taken in a lump of 300 lbs. or 400 lbs. and placed under a steam hammer. After being worked into a bloom, it is put into a furnace, reheated and rehammered two or three times, when it is ready to roll into slabs 2 ins. or 3 ins thick. This unlaminated iron is used for topping rails—process not costly; one steam-hammer, two refineries, and two heating furnaces being capable of making 60 tons of bloom per week. Rails of this make, down one year, with traffic of 130 trains per day over them, showed no signs of wear, and at Cwm Avon had already worn out two sets of iron rails made under ordinary specifications.

TREATMENT OF STEEL PLATES,

AS EFFECTED BY PUNCHING, DRILLING, AND ANNEALING.

The tensile strength of a steel plate, with proper degree of hardness, should give an ultimate strength of 33 to 35 tons per square inch.

The denser the metal the more injurious the effect of punching. Steel plates of from 33 to 35 tons per square inch tensile strength, suffer more by punching than iron plates of from 20 to 22 tons per square inch, unless the steel plates are annealed after being punched.

Effect of Annealing the Plates.—The plates which had been punched were annealed, when the tensile strength of plate rose to 35.86 tons per square inch, or to its original strength. The mean results obtained of experiments of strength of drilled plates riveted together, and of punched plates annealed and riveted together—plates off of same piece—gave for drilled

plates 41.075 tons per square inch, and for the punched 41.24 tons per square inch, showing the punched plate when annealed to be equal to the drilled, if the latter is properly annealed. Plates were 5-16 inch thick, rivets 9-16 inch diameter, 1⅜ centre to centre, and double riveted.

Mr. Henry Sharp found the effect of drilling and punching steel plates to be as follows:

Number of Test.	Thickness.	Area.	Breaking Weight on Lever.	Weight per Square Inch of Section when Drilled.	Weight per Square Inch of Section when Punched.
			Tons. Cwt.		
1 D	5-16	0.5437	19. 3	35.22	.....
1 P	5-16	0.55625	14. 17	.....	26.690
2 D	5-16	0.55	20. 10	37.27	.....
2 P	5-16	0.5625	13. 5½	.....	23.735
3 D	5-16	0.5466	19. 18	36.40	.....
3 P	5-16	0.5593	12. 12½	.....	22.570

Thus proving that punching deteriorated the tensile strength of steel plates, 5-16 inch thick, to the extent of from 26.4 to 37.8 per cent., as compared with drilling, or on an average of 33 per cent. On examining a section of steel or iron plates which has been punched, it will be found that the metal is more or less hard and brittle around the hole (the thicker and harder the plate, the greater the distance).

Effect of Taper Punching on Steel Plates.—Plate ½ inch thick, cut in two, one piece, punched with a punch ⅞ inch diameter, clearance being 1-16 inch hole in die. The other plate was punched with the same punch, but clearance in hole being 3-16, making a taper hole in the plate. The ultimate tensile strength of plates, unannealed after being punched, was for the taper hole 32.527 tons per square inch of net sectional area; for the straight hole, 26 tons, being 25 per cent. in favor of the taper-punched hole, the fracture of the taper-punched plates being more fibrous than the other.

Shrinkage of Cast-Steel Tyres.

Rules adopted by W. A. Robinson, Esq., Mechanical Superintendent Great Western Railway, Canada.

"The following instructions are to be strictly observed in shrinking and fastening on CAST-STEEL TYRES:

"*1st*—Both tyre and wheel must be perfectly cylindrical.

"*2d*—These tyres are to have allowed them in their cold state the amount of shrinkage shown in the following table, according to their respective diameters:

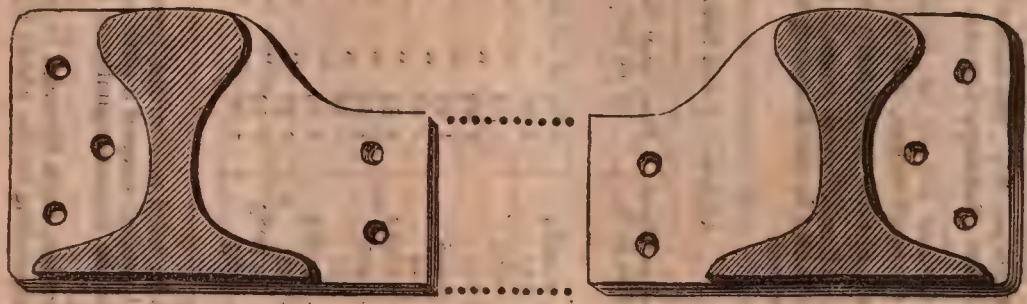
Letter of Tyre.	Internal Diameter of Tyres.		Allowance for Shrinkage.		
			Decimal Parts of an Inch.	Fractional Parts of an Inch.	Wire Gauge.
	Ft.	Ins.			
A	2	2¼	.014583	1-69 of an inch.	28
B	2	8	.017	1-56 " "	27
C	2	9	.0183	1-54 " "	26
E	3	2	.021	1-49 " "	25
F	3	4½	.0225	1-44 " "	24
G	3	8	024	1-41 " "	23
H	4	3¼	.028472	1-35 " "	22
J	4	7	.0305	1-33 " "	21
K	4	8	.031	1-32 " "	21
L	5	2¼	.034583	1-29 " "	20
M	5	3	.035	2-57 " "	20
N	5	7⅞	.0377083	2-53 " "	20
O	5	9	.0383	1-26 " "	19

"*3d*—Wood only is to be used to heat the tyres, and the temperature must not be allowed to exceed a dark red glow in the shade, and all parts must be heated equally, to insure uniform hardness and roundness."

To facilitate the operation, each foreman is provided with a set of steel gauges corresponding to the above figures.

WHEEL GAUGE,

For Determining Position of Wheel on the Axle.



THE RAMAPO WHEEL AND FOUNDRY CO.,

On application, will furnish castings for a gauge. By fastening the castings to a wooden straight-edge, distance between the inside of rails agreeing with distance between rails on the railway track, the proper position of wheel, showing *clearance* in relation to the rail, will be seen.

"FATIGUE" OF METALS.

Effect of Strains upon Railway Axles of Iron and Steel.

(*Compiled from "Engineering."*)

It is known, through the experiments of Mr. W. Fairbairn and others, that the repeated application and removal of a load which is considerably below the breaking weight of any metallic bar, will, after a number of such repeated applications, cause a fracture of the bar. This anomaly has been called the "*fatigue of metals.*"

To test the value of steel and iron for axles, and the effect of strains, similar to those imposed upon car axles in service, Mr. Wöhler, Chief Engineer of the Prussian State Railway, constructed machines for testing axles, by which the bars were exposed to vibrating actions and repeated strains, within adjustable limits.

1st—*For straining a cylindrical bar in a manner similar to that in which a railway axle is acted upon by the load it carries.*—A bar placed in bearings was caused to revolve, to one end (corresponding to journal of an axle) was attached a spring, which gave a constant downward pull, by which action the bar was bent down at the end to a fixed distance, and in its rotation the action of the spring caused it to bend in all directions successively all round the circumference of the bar, by which means the bar was bent and unbent in each rotation, giving alternate strains of compression and tension.

The breaking strain of bars of best fibrous iron in these conditions was no higher than 9 to 10 tons per square inch; soft steel, 12 to 15 tons per square inch, or 15 tons in tension, 15 tons in compression. A broken bar of fibrous iron which bore 19,000,000 of such alternate strains, broke with a strain of 9 tons per square inch of section, taking the total difference of change, from a compression of 9 tons to a tension of 9 tons, it is 18 tons, or nearly the tenacity of this material when strained in one direction only.

2d—*To test the effect of repeated strains applied to the centre of a revolving axle, in which the fibres in each section are strained in the same direction each time, the tension upon each fibre varying between zero and the strain imposed.*—Fibrous iron bars broke with a tensile strain of 15 to 18 tons; soft steel, with strains of between 22½ to 25 tons on the square inch.

3d—*To test the amount of strain such bars would bear if the strain applied in one direction was not taken off entirely, but only partly removed each time.*—The remarkable fact was shown that a steel bar may be strained to 40 tons on the square inch, and released to a tension of 20 tons, with the

same degree of safety as a tension varying between 12½ tons and 35 tons would give; or a steel bar can be loaded and unloaded between 20 and 40 tons strain per square inch,

with safety; while it will break down if the load of 40 tons is altogether removed each time, or it will equally break down with a load of 15 tons when the latter is applied in opposite directions alternately—proving that the fatigue of metals or resistance to alternating and repeated strains does not correspond to the absolute amount of strains repeatedly exerted upon them, but to the difference between the limits of variation of these strains. The total variation equal to the absolute breaking weight of fibrous iron has been found to be between 15 and 18 tons, and for the best soft cast steel between 22½ and 25 tons per square inch. Within the static limits of elasticity the same amount of variation is admissible, with equal safety, no matter in what manner the total difference between the strains is arrived at.

4th—*The effect of a sudden change of section* (*similar to that made in turning a journal in an axle*).—Showed the strength to be at the spot where the sudden change of section takes place, between ¼ to ⅓ below the strength of the straight bar; that a round hollow of sufficiently large diameter does not cause such a weakening effect upon a steel bar as a right angle, the sharp corner of the latter interfering with the flexibility of the bar, concentrates the action of the bending force upon a more limited space, making it less capable to resist the effects of vibration. Figures 1, 2, and 3, show fractures of bars with partly removed collars; Figure 4, with a complete collar; the black denoting fine soft steel of gray color, the rest a whitish close-grained fracture and a wavy surface; showing the fracture to have taken place around the collar at first, and the bar to have given away when the crevice had reached deep enough to the centre to reduce the unbroken portion below the ultimate limit of strength.

5th—Mr. Wöhler has established the fact that the strength of a steel bar is reduced about one-third by the influence of a moderate pressure by a surrounding mass (as on an axle fitted into a car wheel), fracture being similar to No. 5, which will explain the cause of axles breaking next to the hub of wheels. Figures 6 and 7 show fractures of steel under normal conditions, the radial shades on No. 7 not being cracks or fissures, but shadows cast by higher portions.

6th—*No crystallization by continual use* was found in a bar which had been tested after receiving 19,000,000 vibrations—proving that the alternate bending had no tendency to change the nature of the metal and induce crystallization, the section tested being as fibrous as the original bar from which it was made.

Experiments on the "Fatigue" of Bessemer Steel.

By M. Joseph V. Stummer, Northern Railway of Austria.

7th—Axles 6 feet 8¼ inches long, 4⅝ inches diameter; journals 6½ inches long, 3¼ inches diameter, placed on supporting blocks from 3 feet 3 inches to 5 feet apart; weight of ram, 653 and 612 pounds, falling on centre of axle.

Bessemer steel axles were found to bear 1,000,000 foot pounds of blows applied to the alteration of the molecular arrangement. Iron axles broke with 500,000 and 350,000 foot pounds. Hollow iron axles bore same amount as solid iron, but with less regular results.

8th—Bessemer steel axles were found to show double cohesive strength in every sense, as compared with the best Styrian or English axles; the same weight falling the same height only produced half the deflection of the steel axle, and to obtain the same deflection as with iron the number of foot pounds exerted by the falling weight had to be doubled.

9th—That a blow of 30,000 foot pounds applied at once to a new axle, caused immediate fracture, while repeated blows, gradually increasing in force, could be applied to a higher limit without producing the same effect.

10th—That the *neutral fibre*, or point separating fibres in tension from those of compression, lie nearest to the upper surface in the hardest kind of steel, and descend gradually to the lower surface, the softer the steel is made, indicating a varying rate or proportion between the tensile and compressive strength of steel of different degrees of hardness.

11th—That, by repeated strains, exceeding the elastic limit, the strength of Bessemer steel is gradually increasing, at the

expense of its softness or malleability, but the changes are very gradual and within narrow limits.

12th—That similar changes take place in the softest irons, only the decrease of malleability is quicker and less regular than in the case of Bessemer steel and iron; for this reason is more treacherous under loads.

Table of Tensile Strength of Steel containing Different Proportions of Carbon.

By Thomas E. Vickers.

Softest, or least carbonized steel, containing .33 per cent. carbon, marked No. 2.

The hardest, or most highly carbonized, containing 1.25 per cent. carbon, No. 20; the intermediate numbers representing intermediate degrees of carbonization.

Description of Steel.	Proportion of Carbon.	Break'g Strain per Sq. In.	Elongation.	Specific Gravity.
	Per Cent. [Approximate.]	Tons.	Inches.	
No. 2	0.33	30.4	1.37	7.871
No. 4	0.43	34.0	1.37	7.867
No. 5	0.48	37.5	1.25	7.855
No. 6	0.53	42.5	1.12	7.855
No. 7	0.58	41.5+	0.81	7.852
No. 8	0.63	45.0	1.00	7.848
No. 10	0.74	45.5	0.69	7.847
No. 12	0.84	55.0	1.12	7.840
No. 15	1.00	60.0	1.00	7.836
No. 20	1.25	69.0	0.62	7.823

Tensile strength is increased by the addition of carbon until the steel contains 1.25 per cent., when it sustains about 69 tons per square inch; beyond this degree of carbonization the steel becomes weaker, until it reaches the form of cast-iron.

Table of Transverse Strength of Axles made of Steel, containing Different Proportions of Carbon.

Axles turned to 3.94 inches diameter at centre, 4.25 at the ends, placed on bearings 3 feet apart; ram weighed 1,547 lbs.; dropped on centre of axle from height of 1 foot, increasing up to 36 feet fall.

Material of Axle.	Proportion of Carbon. [Approx.]	Total No. of Blows.	Height of Fall in Last Blow.	No. of Blows Sustained from 36 feet High.	Sum of Deflection
	Per Cent.		Feet.		Inches.
Steel No. 2.	0.33	17	36	4	58.81
" " 4.	0.43	18	36	5	56.00
" " 5.	0.48	18	36	5	53.56
" " 6.	0.53	15	36	2	35.06
" " 7.	0.58	16	36	3	38.81
" " 8.	0.63	18	36	5	46.00
" " 10.	0.74	16	36	3	40.31
" " 12.	0.84	10	20	0	8.56
" " 15.	1.00	8	12½	0	4.31
" " 20.	1.25	10	20	0	6.94
Best Wrought-Iron....		13*	36	0	31.19
Scrap Iron.....		5	5	0	2.00
" "		5†	5	0	3.69

* Cracks began to show at 10 lb. blow, with 20 feet height of fall, and increased with each subsequent blow.

† Two large cracks opened at 5 lb. blow, and considered as broken.

To Calculate Force of a Blow by a Weight Falling on an Axle.

To find quantity of work (or force of blow) of a ball falling from a given height, at moment of impact.

Rule—Multiply weight of ball by distance passed over; result = lbs. feet.

Ex.—With what force does a ball with 1,650 lbs. strike, in falling 35 feet? Ans. 1,650 × 35 = 57,750 lbs. feet = 28 tons.

To Find Breaking Weight, in Tons, of an Axle placed on Supports.

Rule—Cube of the diameter of axle, in inches × 0.9 for ordinary rolled iron; by 2.934 for hammered iron; by 4.254 for Mersey Steel and Iron Co.'s steel; the sum divided by length between supports, in feet, equals weight in tons, nearly.

Ex.—What is approximate breaking weight of a hammered axle, 4 inches at centre, distance between supports 5 feet.

$$4^3 = 64; \text{ then } \frac{64 \times 2.934}{5} = 37.5 \text{ tons.}$$

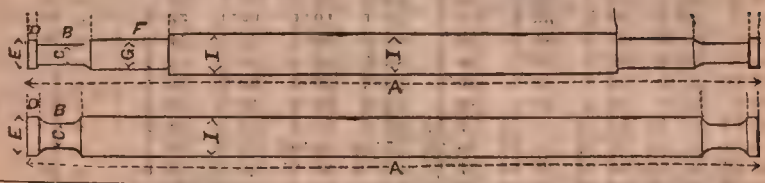
Table to find Weight of Railway Axle Iron (Rolled).

A. & P. Roberts & Co., Pencoyd Iron Works, Phila.

Length.	Diameter.								
	3 Ins.	3¼ Ins.	3½ Ins.	3¾ Ins.	4 Ins.	4⅛ Ins.	4¼ Ins.	4⅜ Ins.	4½ Ins.
7 ft.	164.92	193.55	224.49	257.67	293.16	311.78	330.96	350.77	371.07
6 ".....	141.36	165.9	192.42	220.86	251.28	267.24	283.68	300.66	318.06
1 ".....	23.56	27.65	32.07	36.81	41.88	44.54	47.28	50.11	53.01
11 in..	21.59	25.34	29.40	33.74	38.39	40.82	43.34	45.93	48.59
10 " ..	19.63	23.04	26.72	30.67	34.90	37.11	39.40	41.76	44.17
9 " ..	17.67	20.73	24.05	27.61	31.41	33.40	35.46	37.58	39.76
8 " ..	15.70	18.43	21.38	24.54	27.92	29.69	31.52	33.41	35.34
7 " ..	13.74	16 12	18.70	21.47	24.43	25.98	27.58	29.23	30.92
6 " .	11.78	13.82	16.03	18.40	20.94	22 27	23.64	25.05	26.50
5 " ..	9.81	11.52	13.36	15.33	17.45	18.56	19.70	20.88	22.09
4 " ..	7.85	9.21	10.69	12.27	13.96	14.85	15.76	16.70	17.67
3 " ..	5.89	6.91	8.02	9.20	10.47	11.13	11.82	12.53	13.25
2 " ..	3.92	4.61	5.34	6.13	6.98	7.42	7.88	8.35	8.83
1 " ..	1.96	2.30	2.67	3.07	3.49	3.71	3.94	4.17	4.42
⅞ " ..	1.71	2.01	2.33	2.68	3.05	3.24	3.44	3.65	3.86
¾ " ..	1.47	1.73	2.00	2.30	2.62	2.78	2.95	3.13	3.31
⅝ " ..	1.22	1.44	1.67	1.91	2.18	2.32	2.46	2.61	2.76
½ " ..	.98	1.15	1.33	1.53	1.74	1.85	1.97	2.08	2.20
⅜ " ..	.73	.86	1.00	1.15	1.31	1.39	1.48	1.56	1.65
¼ " ..	.49	.57	.67	.76	.87	.93	.98	1.04	1.10
⅛ " ..	.24	.28	.33	.38	.43	.46	.49	.52	.55

Weight of Rolled Axles.

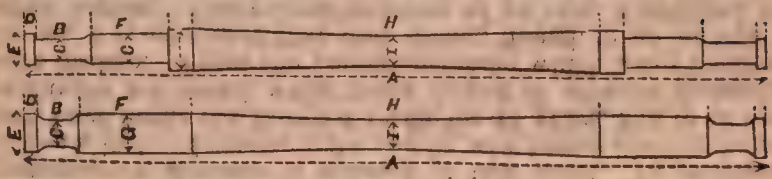
A. & P. Roberts, Pencoyd Iron Works, Phila.



	A—Total Length.	B—Length of Journal.	C—Diam. of Jour.	D—Length of Collar.	E—Diam. of Collar.	F—Length Hub-Seat.	G—Diam. Hub-Seat.	I—Diam. of Middle.	Weight.
	Ft. Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	
Finish ..	6. 9⅓	5 5-16	3¼	½	3⅞	8½	4	4⅛	....
Rough ..	6. 9⅜	4 13-16	3½	⅞	4⅛	..	..	4⅛	293.8
Solid ...	6. 9⅜	....	....	..	..	..	..	4⅛	304.0
Finish ..	6.10¾	7	3¼	½	3⅞	9	4	4⅛	....
Rough ..	6.11	6½	3½	⅞	4⅛	..	..	4⅛	296.3
Solid ...	6.11	....	....	..	..	..	..	4⅛	310.0
Finish ..	6.10½	6½	3	⅝	3¾	8½	3⅞	4	....
Rough ..	6.10¾	6	3¼	1	4	..	..	4	278.0
Solid ...	6.10¾	....	....	..	..	..	..	4	290.4
Finish ..	7. 0½	6¼	3 3-16	⅝	4	10	4⅛	4¼	....
Rough ..	7. 0¾	5¾	3 5-16	1	4¼	..	..	4¼	318.7
Solid ...	7. 0¾	....	....	..	..	..	..	4¼	334.0
Finish ..	6.10½	6½	3½	⅝	4¼	9½	4⅜	4½	....
Rough ..	6.10¾	6	3¾	1	4½	..	..	4½	349.4
Solid ...	6.10¾	....	....		..	..	..	4½	365.6
Finish ..	6.10½	6½	3¼	⅝	4⅛	9	4¼	4⅜	....
Rough ..	6.10¾	6	3½	1	4⅜	..	..	4⅜	327.6
Solid ...	6.10¾	....	....	..		..	..	4⅜	345.5

Weight of Hammered Axles.

A. & P. Roberts, Pencoyd Iron Works, Phila.



	A—Total Length.	B—Length of Jour.	C—Diam. of Jour.	D—Length of Collar.	E—Diam. of Collar.	F—Length Hub-Seat.	G—Diam. Hub-Seat.	H—Length of Taper.	I—Diam. of Middle.	Weight.
	Ft. Ins.	Ins.	Ins	Ins.	Ins.	Ins.	Ins.	Ft. Ins	Ins.	
Finish.	6. 7¼	5	3¼	⅝	3¾	12¾	3⅞	3. 6½	3½	...
Rough.	6. 7½	4½	3½	1	4	13	4	3. 6½	3½	254.2
Solid ..	6. 7½	..	..	..	....	18½	4	3. 6½	3½	262.0
Finish.	6. 6¼	5½	3	⅝	4 3-16	9½	4¼	3.11	3¾	...
Rough.	6. 6½	5	3¼	1	4⅜	9¾	4⅜	3.11	3¾	279.3
Solid ..	6. 6½	..	..	..	....	15¾	4⅜	3.11	3¾	297.3
Finish.	6. 9⅞	4½	3¼	⅝	4	10¾	4⅛	4. 2⅛	3¾	...
Rough.	6.10⅛	4	3½	1	4¼	11	4¼	4. 2⅛	3¾	293.8
Solid ..	6.10⅛	..	..		..	16	4¼	4. 2⅛	3¾	306.0
Finish.	7. 0⅞	5½	3⅛	⅝	4	11¾	4⅛	4. 1⅛	3¾	...
Rough.	7. 1⅛	5	3⅜	1	4¼	12	4¼	4. 1⅛	3¾	302.4
Solid ..	7. 1⅛	..	..	..	..	18	4¼	4. 1⅛	3¾	318 0
Finish.	6. 8½	5	3¼	⅝	4	12¼	4⅛	3. 8¾	3¾	
Rough.	6. 8¾	4½	3½	1	4¼	12½	4¼	3. 8¾	3¾	290.0
Solid ..	6. 8¾	..	..	..	..	18	4¼	3. 8¾	3¾	302.0
Finish.	6. 8¾	5	3¼	⅞	4¼	10¾	4⅜	3.11½	3⅞	...
Rough.	6. 9	4½	3½	1¼	4½	11	4½	3.11½	3⅞	315.0
Solid ..	6. 9	..	..	..	....	16¾	4½	3.11½	3⅞	332.2

Forms of Car Axles.

(*Compiled from Remarks by "Axle," in American Railway Times.*)

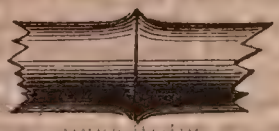
The point where fracture occurs, in originally sound axles, after long-continued use, is almost invariably at the inner end of the hub of the wheel; to determine the causes which produce these results, it must be borne in mind that an axle in use acts as two simple levers: the rails through the wheels are the fulcrums; the short arms the portion of the axle extending from the rail outwards, the long arms the portion of the axle extending inward and united in the middle. The weight of a load carried on a journal, multiplied by the length of a short arm, and divided by the length of the long arm (the part extending to the centre of the track), determines the power required there to balance that weight; this power is furnished by the stiffness of the metal, and the required stiffness is obtained and determined by the quality and diameter of the axle at its centre. That an axle may uniformly absorb the pulsations and shocks transmitted by the inequalities of the track and lurching of the load, delivered by the wheel to the axle to the point next to that at which the wheel is fixed, the diameter of the central portion should decrease from the wheels inward; for the reason, that if the central portions *increase* in diameter *inward*, the mass of metal farthest from the point where it first takes the tremulous strain, is possessed of so much inertia that before it can be overcome and put in motion equally with the rest of the axle, the force is expended, and that part of the axle does not receive and bear its due proportion of fatigue, and would require a period of time unattainable in practice to carry these sudden strains to all the central portions of the axles alike, unless the weight, and, consequently, diameter is reduced at that point. In practice, axles 3¼ inches diameter at the middle, with bosses 4 inches diameter, have borne the heaviest traffic for 18 years, and to all appearances are sound, while those forged of uniform diameter have broken. From the conditions under which axles invariably act, it is necessary that they spring, though in an infinitely small degree. The central portions of an axle, if enlarged in the middle, are shielded from bearing their proper share of the pulsations.

Richmond Iron.

An axle to be of the same relative strength throughout should be of reduced diameter from the wheels inwards, each half having the form of a simple lever, with the greatest diameter over the fulcrum (at the wheel), tapering gradually, and in uniform lines, to the centre, that the pulsations may flow uninterrupted, in all cases avoiding a square neck or shoulder, which D. K. Clark remarks, "is an incipient break, the beginning of a fracture."

Axles with wheels, having a square shoulder or increase of diameter of the axle immediately beyond the wheel, frequently break, for the reason that, under a load on the journal, and with the lateral pressure against that portion of the flange of the wheel in contact with the rail, the metal in the upper portion of the axle is elongated most in the angle, because there the strain is the greatest. The particles at this point have, in a measure, slid along on one another, a portion attached to and going with the body of the axle, and the other portion tending with the wheel in the other direction. When this upper and expanded side is turned beneath, the reverse condition exists; the portion which was compressed is expanded, and the expanded portion is compressed, and the ability of wrought-iron to resist compression being less than its ability to resist extension, the particles cannot be crowded back into their original position. With the alternate and sudden extension and compression, the points along the plane of fracture become less and less pointed, until they each become a small plane in itself. They lose their attachment to the adjacent parts; the metal is called granular, simply because it shows a granular structure at the fracture; the metal in the other parts retains its original and perfect condition. The same laws apply to the furrowing and weakening of boilers, either at the seams or where the attachments of pieces are made, and where constant vibrations are imparted, and only remedied by thinning both edges of a taper to nothing. To remedy the defect of breakage of wheels and axles, it is requisite that the wheel and the axle should be so connected that the same conditions as regards angles and abrupt changes, in form and strength, shall apply to the structure as a whole, as it does to axles themselves. To do this, the boss of the axle must be enlarged over and above the next inner portion, that a

curve may be formed immediately at the inner end of the hub of the wheel, that the axle may virtually become a part of the hub of the wheel; that in practice there may be no beginning of the one or ending of the other, the fillet being as per sketch.



In this form the vibrations would find no angles in which to concentrate, but they would be carried to and rendered harmless by all the central parts of the axle; granulation of the metal would cease, and the durability of the axle increased.

For effects of strains upon axles, see Fatigue of Metals.

Dimensions of Axle Journals.

By experiments of Mr. Geo. Rennie it was found that the resistance from friction on an axle was directly as its diameter, and but one-half in terms of its length; also that the length of the bearing should be twice its diameter; that the area of the bearing surface should not be subject to a greater pressing weight than 90 lbs. per square inch.

The friction of the journal of an axle which presses on one side only, as in a worn journal bearing, is less than when it presses at all points, the difference being about .005.

If the journal of an axle lies in a triangular formed bearing, the friction is double that of a cylindrical bearing.

To Calculate the Mechanical Effect of Friction on the Journal of an Axle.

p = Ratio of circumference of a circle to its diameter.
t = Number of revolutions
R = Radius of journal, in feet.
W = Weight on journal.
f = Coefficient of friction.

$$\frac{p\ t\ f\ W\ R}{30} = F$$

What would be the mechanical effect of friction on a journal 3.5 ins. diameter, load on it 6,000 lbs., making 336 revolutions per minute?

Coefficient of friction .16; then

$$\frac{3.1416 \times 336 \times .16 \times 6000 \times .1458}{30} = \frac{17391}{30} = 579.7 \text{ lbs.}$$

Corresponding to the friction on a car axle journal 3½ ins. diameter, with a load of 3 tons on it, with a 30-inch wheel, moving at rate of 30 miles an hour.

Dimensions of Car Axles in Service.

Pennsylvania R. R.—4 ft. 8½ ins. Gauge.

Standard gauge for fitting up wheels, adapted for 4 ft. 8½ ins. and 4 ft. 10 ins. gauge, is 4 ft. 8¼ ins. between track lines, measured from outside to outside of wheel flanges.

Passenger Car Axles—Steel.—Whole length, 6 ft. 10¾ ins.; diameter next to wheel-fit, 4⅜ ins.; diameter of wheel-fit, 4¼ ins.; diameter at centre of axle, 3 15-16 ins.; journal 7 ins. long, 3¼ ins. diameter; collar at each end, ½ in.

Freight Car Axle.—Whole length of axle, 6 ft. 10¾ ins.; diameter of axle next to wheel-fit, 4⅛ ins.; wheel-fit, 4 ins.; diameter at centre of axle, 4⅛ ins.; journals 7 ins. long, 3¼ ins. diameter; collars at each end, ½ in., 3⅞ ins. diameter.

Catawissa R. R.—4 ft. 8½ in. Gauge—Freight.

Length of axle	6 ft. 9½ ins.	Diameter of shoulder	3⅝ ins.
Diameter	4¼ "	Length of collar	½ "
L'gth of hub of wheel	6½ "	Diameter "	3⅞ "
Bore " "	4⅛ "	Recession of hub of wheel from outside edge of tread	1⅛ "
Projection of hub inside beyond inside of flange	1 "	Width between flanges at tread	4 ft. 8 "
Length of journal	5½ "	Width between flanges inside	4 ft. 5 "
Diameter "	3¼ "		
Length of shoulder	2½ "		

Ramapo Wheel and Foundry Co.

Morris and Essex R. R.—4 ft. 8½ in. Gauge.

Passenger and Freight Axle—Hammered Iron.—Total length, 6 ft. 9½ ins.; diameter next to wheel-fit, 4½ ins.; wheel-fit, 4 ins.; diameter at centre, 3⅞ ins.; journal 6 ins. long × 3¼ ins. diameter; collars, ½ in. × 3 15-16 ins. diameter; shoulders next to wheel-fit 4 ins. diameter × 2 ins. long; track gauge between flanges, 4 ft. 8¼ ins.

Union Line—4 ft. 8½ in. Gauge.

Similar to Pennsylvania R. R. freight car axle.

Empire Line—4 ft. 8½ in. Gauge.

Whole length, 6 ft. 9½ ins., 4⅛ ins. diameter—straight; wheel-fit, 4 ins.; journals, 5⅜ ins. long, 3¼ ins. diameter; collars, ½ in. thick, 3⅞ ins. diameter; track gauge, 4 ft. 8¼ ins.

Blue Line—4 ft. 8½ ins. Gauge.

Total length, 6 ft. 6⅝ ins.; centres of journals, 6 ft. 3-16 in.; diameter 1¾ ins. beyond wheel-fit, 4¾ ins., tapering from wheel-fit; diameter of wheel-fit, 4⅝ ins.; diameter of centre of axle, 4 ins.; length of wheel-fit, 8 5-16 ins.; journals 5 3-16 ins. long, 3 3-16 ins. diameter; collars ⅝ ins., 3 21-32 ins. diameter; shoulder between journal and wheel-fit, 2 ins. long, 3 29-32 ins. diameter.

Hudson River R. R.—4 ft. 8½ ins. Gauge.

Passenger and Freight Axle.—Total length, 6 ft. 9 ins.; diameter next to wheel-fit, 4½ ins.; at centre, 3¾ ins.; journal 5½ ins. long, 3⅜ ins. diameter; collars, ¾ ins., 4 3-16 ins. diameter; wheel-fit, 4¼ ins.; the fit at back of hub, for ½ an inch, has a taper of ¼ inch to the inch projecting into wheel when in place; length of hub of wheel, 7 ins.; axle, straight, 2 ft. 1 in. from journal; track line, 4 ft. 7⅞ ins., giving ⅝ ins. play for flanges.

Great Western R. R. of Canada.

Pullman's Sleeping Car—Standard Axle—4 ft. 8½ ins. Gauge.—Total length of axle, 6 ft. 9½ ins.; centres of journals, 6 ft. 2¼ ins.; diameter 1¾ ins. beyond wheel-fit, 4¾ ins., tapering from wheel-fit; diameter of wheel-fit, 4⅝ ins.; diameter of

centre of axle, 4 ins.; length of wheel-fit, 8 5-16 ins.; journals, 6 ins. long; 3 3-16 ins. diameter; collars, ⅝ ins., 3¾ ins. diameter; shoulder between journal and wheel-fit, 2¼ ins., 3¾ ins. diameter.

Standard Car Axle—5 ft. 6 ins. Gauge.—Total length of axle, 7 ft. 7¼ ins.; centres of journals, 7 ft. ¾ in.; diameter 1¾ ins. beyond wheel-fit, 4¾ ins., tapering from wheel-fit; diameter of wheel-fit, 4⅝ ins.; diameter of centre of axle, 4 ins.; length of wheel-fit, 8 13-16 ins.; journals, 5½ ins. long, 3 7-16 ins. diameter; collars, ½ inch, 4 ins. diameter; shoulder between journal and wheel-fit, 1⅝ ins., 4 ins. diameter.

Erie Railway—6 feet Gauge.

Passenger Axle.—Total length, 8 ft. 1 in.; 5 ft. 4⅝ ins. between shoulders; diameter next to wheel-fit, 4¾ ins.; at centre, 4 ins.; wheel-fit, 4⅝ ins., 7 3-16 ins. long; journals, 3½ ins. diameter, 7 ins. long; collars, ½ in. thick, 4¼ ins. diameter; shoulder between journal and wheel-fit, 1½ ins. long, 4½ ins. diameter; wheel-fit has taper of 1-16 in. in diameter in 1 ft.

Freight Axle.—Total length, 8 ft.; between shoulders, 5 ft. 4⅝ ins.; diameter next to wheel-fit, 4½ ins.; at centre, 3¾ ins.; wheel-fit, 4⅜ ins, 7 3-16 ins. long; journals, 3¼ ins. diameter, 6 ins. long; collars, ½ in. thick, 4 ins diameter; shoulder between journal and wheel-fit, 2 ins.

Effect of Wear on Strength of Car Axles.

Test for new steel axles: 5 blows of a ram, weighing 1,650 lbs., falling 30 feet, on axle placed on supports 3 feet apart.

Test for new iron axles: 5 blows of a ram, weighing 1,650 lbs., falling 20 feet, on axle placed on supports 3 feet apart.

New Steel Axles—"Vicker's"—3 15-16 ins. diam. at centre.

Blow.	Fall.	Position.	Result.
1	25 feet.	—	11⅜ inch deflection.
2	25 "	⌒	Straightened.
3	25 "	—	9½ inch deflection.

Ramapo Wheel and Foundry Co.

New Steel Axles—Continued.

Blow.	Fall.	Position.	Result.
4	25 feet.	⌒	11⅜ inch, deflection 1⅞
5	25 "	⌒	10⅞ " " 9
6	35 "	⌒	15⅜ " " 6⅜
7	35 "	⌒	14⅞ " " 8½
8	35 "	⌒	15 " " 6½
9	38 "	⌒	16½ withdrawn.

S. Butcher's New Steel Freight Axle--4⅛ ins. diam

Blow.	Fall.	Position.	Result.
1	15 feet.	—	4⅜ inch deflection.
2	16 "	⌒	6⅛ " "
3	15 "	⌒	5⅝ " "
4	16 "	⌒	5⅞ " "
5	15 "	⌒	5⅝ " "
6	21 "	⌒	7⅜ " "
7	20 "	⌒	Broken.

Kloman's New Rolled Iron Passenger Car Axle.

4½ ins. diam.

Blow.	Fall.	Position.	Result.
1	20 feet.	—	5¾ inch deflection.
2	20 "	⌒	Straightened.
3	30 "	—	7⅜ inch deflection.
4	30 "	⌒	Broken.

Rolled Iron Axle—4 ins. diam.—(Maker's name omitted.)

1 blow, fall 13 feet, position —, 5¼ inch deflection.
2 " " 12 " " ⌒, broken.

Hammered Iron Axle—4 9-16 ins. diameter.

1 blow, fall 12 feet, position —, 3¼ inch deflection.
2 " " 12 " " ⌣, 2¾ " "
3 " " 17 " " ⌒, nearly straight.
4 " " 18 " " —, broken.

Effect of Wear on Vicker's Steel Passenger Axle—3 15-16 ins. diameter—put in service Dec., 1866, in use until May, 1868, with blow of ram of 1,650 lbs. :

1 blow, fall 20 feet, position —, 9 inch deflection.
2 " " 25 " " ⌒, broken.

Effect of Wear on Chas. Cammell's Short Journal Freight Axle, put in service Oct., 1865, in service until May, 1868 :

1 blow, fall 20 feet, position —, 9⅛ inch deflection.
2 " " 25 " " ⌒, broken.

Effect of Wear on Steel Passenger Axle—Vicker's—put in service Nov., 1867, in service until April, 1868 ; diameter at centre, 4⅜, wheel-fit, 4½ ins. :

1 blow, fall 25 feet, position —, 7¾ inch deflection.
2 " " 25 " " ⌒, straightened.
3 " " 25 " " —, 6⅞ inch deflection.
4 " " 25 " " ⌒, broken in 3 pieces.

Steel Axle, put in service Aug., 1867, tested April, 1868 ; axle 4⅜ ins. diameter at centre, 4½ ins. at wheel-fit :

1 blow, of fall of 25 feet, position —, 6⅜ inch deflection, journal broke off at shoulder.
2 " " 25 " " ⌒, broken in 3 pieces.

Steel Axle—Sleeping Coach—put in service Feb., 1867, tested 16th of April, 1868 ; axle 3 15-16 ins. diameter at centre, 4¼ ins. at wheel-fit :

1 blow, of 1,650-lb. ram, falling 25 feet, broke it in 3 pieces.

Steel Freight Axle, annealed in ashes :

1 blow, fall 15 feet, position —, 4⅝ inch deflection.
2 " " 15 " " ⌒, broken.

Wear of Railway Axles and Boxes.

(Michigan Central R'y.)

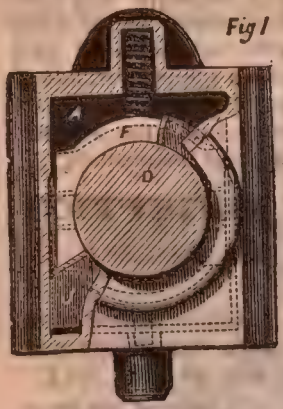
Years.	1862.	1863.	1864.	1865.	1866.	1867.
Mileage of f'ht trains.	463,112	564,827	542,410	485,275	533,451	578,177
" pass. "	308,828	447,361	645,759	852,889	902,826	823,474
Total miles.....	771,940	1,012,188	1,188,169	1,338,164	1,436,277	1,401,651
	Iron Axles under Cars.					
No. in use.....	5,606	5,788	5,662	6,788	5,084	6,274
No. renewed.....	497	561	483	684	427	910
Per cent. of renewals.	8.86	9.70	8.50	11.81	8.40	14.54
Av. mileage of axles worn out.....	160,411	195,395	194,416	122,189	232,874	106,232
	Gun Metal Axle Boxes.					
Passenger Cars:						
No. boxes in use.....	960	960	832	982	876	972
No. renewed.....	421	480	1,114	933	782	1,078
Per cent. of renewals.	43.85	50.0	134.00	95.00	89.27	110.90
Av. mileage of boxes worn out.....	31,709	54,284	30,962	46,416	49,536	32,629
Baggage Cars:						
No. boxes in use.....	220	220	180	168	160	200
No. boxes renewed..	191	146	247	174	189	155
Per cent. of renewals.	86.82	66.36	137.00	103.00	118.00	77.50
Av. mileage of boxes worn out.....	45,110	64,852	37,020	51,448	45,721	75,677
Freight Cars:						
No. boxes in use....	10,032	10,376	10,312	10,424	10,168	11,[illegible]76
No. renewed.....	1,969	2,046	2,441	2,910	1,625	3,219
Per cent. of renewals.	19.63	19.62	23.00	27.91	15.98	2[illegible].29
Av. mileage of boxes worn out.....	44,560	93,084	41,405	59,144	89,662	69,[illegible]24
Total per cent. of renewals of all classes of cars.....	23.91	23.12	42.00	34.70	23.17	35.48
Average mileage of all boxes worn out....	59,474	82,048	39,410	41,610	76,723	43,426

OIL-SAVING AXLE BOX.

By William A. Boyden, Altoona, Blair Co., Pa.

The object of this box is the more effectual retaining the lubricant, and excluding dust or dirt from access to the journal, through the back of the box, thus avoiding hot journals.

The great difficulty heretofore connected with improvements of this character, has been their complication and cost.



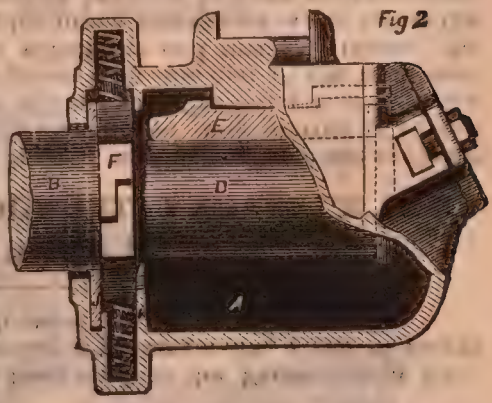


Fig. 1 represents a cross section, and Fig. 2 a vertical longitudinal section. A represents the box or casing of the apparatus in which the lubricating material is placed. The cylindrical end portion of the axle is shown at B, the end passing into the case, A, through the circular hole at back of box. The journal, D, is formed on the end of the axle, and made of a reduced diameter, and fitted into the under side of the bearing, E, which is secured in the upper part of the casing, A, and constituting a portion of the axle box, of which the case forms the other part. Fitted upon the axle, B, within the case, A, and near the outer end of the journal, D, are two semi-circular packing-plates, F, which are placed one upon the upper and the other on the lower side of each part of the axle, and are each rebated at their two ends, so that lips or tongues are formed, the lips upon one of the plates lapping past or upon those of the other in such a manner as to break the joints where the ends of the two plates are brought together, as shown more fully in Fig. 2. Each of the plates is provided with a vertical stem, G, which projects into a cylindrical recess or socket, H, provided in the adjacent side of the case, A, the stems being surrounded by spiral springs, I, which press the plates, F, inward, with their

Ramapo Wheel and Foundry Co.

inner surfaces in snug contact with the cylindrical portion of the axle upon which the plates are situated. Placed around the axle, between the plates, F, and the contiguous end of the case, A, is a washer, J, which may be of leather or any suitable material; the plates, F, are kept in contact with the washer, J, by vertical partition plates, K, formed transversely upon the top and bottom of the case.

The case, A, has, of course, a suitable quantity of lubricating material placed in it, which lubricates the journal, D, to the required degree, this material being prevented from escaping or working out from the case around the cylindrical portion of the axle by the packing plates, F, pressed closely on it by the springs, I, and the leaking of the lubricant at the junction of the extremities of the plates being guarded against by the lapping past each other of the lips left upon the extremities by rebating them. The washer, J, by forming a close packing between the plates and the contiguous end of the case, A, prevents the outward passage of any portion of the lubricant that may find its way above or below the packing plates, the lubricant being by these means effectually retained within the case, thereby securing its most efficient and economical action in lubricating the journal.

This form of box has been used by the Pennsylvania Railroad Company, where, under a passenger-car, a run of 20,258 miles has been made with one oiling.

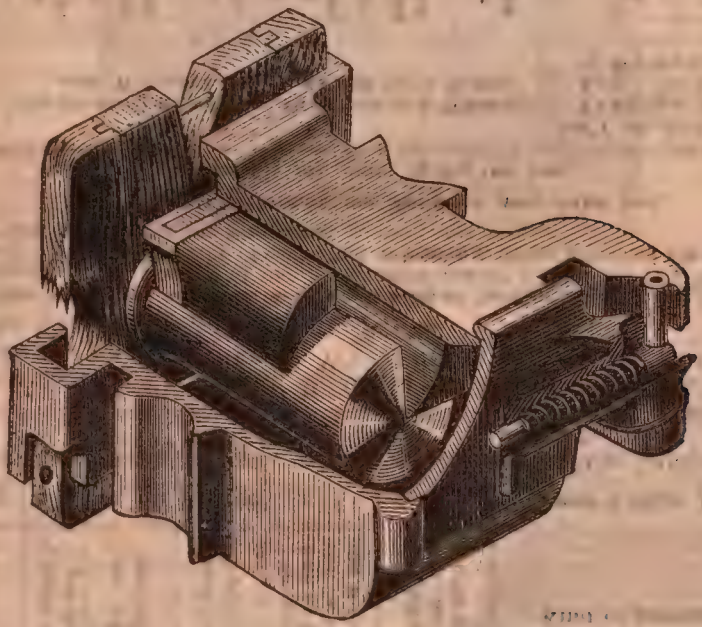
R. C. Wright's Plan of

COLLARLESS JOURNAL AND AXLE BOX.

This journal and brass bearing, as differing from the ordinary journal with one collar, is as follows: The journal is turned straight, without a collar at the end; the brass bearing has a projection which extends down over the end of the axle one-half its diameter, against which the end thrust is taken; the back of the brass bearing fits into a recess cast in the top of the axle box, allowing the bearing brass to be worn very thin, and is the only casting used inside of the box, obviating the use of wedge-plates, moving of the bearings and the small iron thrust-plates.

By this form of journal, its diameter can be increased and its length made as much longer as the usual thickness of collar—say ½ to ¾ inch; corresponding weight of metal and labor in forging, and time in fitting, are saved. Old axles with worn-out collars may be renewed by being upset, trued up, and the collars

turned off. It is claimed that the tendency to end-play is entirely obviated, being taken up by the end-bearing of the brass; that the deeper form of brass used will outwear the ordinary brasses, obviating the cost of renewal of new ones, and saving of oil expended in lubricating new journals; that a great saving of oil is made, as the end of the axle is always lubricated, and hot journals obviated. At the back of the box is a self-operating backing of wood, having up and down movement with the axle, applied from the outside. It is of cheap construction, durable, and entirely excludes dust, and retains the oil.



The following are tests of quantity oils used and wear of brasses on the Atlantic and Great Western Railway—6 feet gauge:

Ramapo Wheel and Foundry Co.

Comparative Cost of Oil to Run Collarless or Collar Journals.

No. of Coach.	Quarts of Oil per Box.	Cost of Oil per Gallon.	Total Cost of Oil per Coach.	Average Miles Run by Boxes, before requiring Re-oiling.	Miles Run, per box, for 1 cts. worth of Oil.	Kind of Bearing.
173	3¾	$1 60	$12 00	2,180	$1\frac{81}{100}$	Former Collar Jour.
190	2½	1 66	8 30	2,686	$3\frac{23}{100}$	Wright's Collarless Jour.

Performance of Axle Bearings, under Coach No. 250, Atlantic and Great Western Railway, from Oct. 15 to Dec. 7, 1867—9,655 Miles.

This coach had one truck with each kind of bearing, they being of the same quality of brass, and using the same quality of oil; the trial being made to test the mileage of each kind of bearing, doing precisely the same service, and having the same care.

R. C. Wright's Collarless Journal and Axle Box.

Journal 3¼ ins. diam. by 6½ ins. long.

No. of Box.	Original Dimensions and Weights.			Dimensions & Weights after 9,655 Miles.			Am't of End and Vertical Wear and Decrease in Weights.		
	Length in inches.	Thickness in inches.	Weight in ounces.	Length in inches.	Thickness in inches.	Weight in ounces.	End Wear.	Vertical Wear.	Weight in ounces.
1	$6\frac{5}{16}$	$1\frac{1}{16}$	178	$6\frac{3}{8}$	$\frac{57}{64}$	164	$\frac{1}{16}$	$\frac{11}{64}$	14
2	$6\frac{5}{16}$	$1\frac{1}{16}$	180	$6\frac{13}{32}$	$\frac{15}{16}$	$166\frac{1}{2}$	$\frac{3}{32}$	$\frac{1}{8}$	$13\frac{1}{2}$
3	$6\frac{1}{4}$	$1\frac{1}{16}$	178	$6\frac{3}{8}$	$\frac{57}{64}$	$164\frac{1}{2}$	$\frac{1}{8}$	$\frac{11}{64}$	$13\frac{1}{2}$
4	$6\frac{9}{32}$	$1\frac{1}{16}$	180	$6\frac{5}{16}$	$\frac{7}{8}$	$165\frac{1}{2}$	$\frac{1}{32}$	$\frac{3}{16}$	$14\frac{1}{2}$
Average of each							$\frac{5}{64}$	$\frac{21}{128}$	$13\frac{87}{100}$

COLLAR JOURNAL.

3¼ ins. diam. by 6 ins. long.

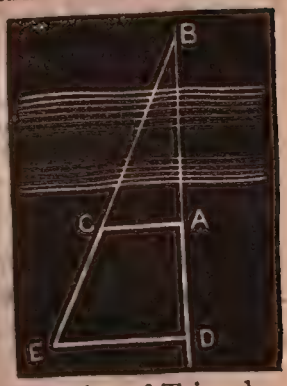
1	$5\frac{11}{16}$	$1\frac{5}{32}$	100	$5\frac{3}{16}$	$\frac{31}{64}$	50	$\frac{1}{2}$	$\frac{43}{64}$	50
2	$5\frac{3}{4}$	$1\frac{11}{64}$	104	$4\frac{7}{8}$	$\frac{3}{4}$	68	$\frac{7}{8}$	$\frac{27}{64}$	36
3	$5\frac{11}{16}$	$1\frac{1}{8}$	100	5	$\frac{43}{64}$	62	$\frac{11}{16}$	$\frac{29}{64}$	38
4	$5\frac{11}{16}$	$1\frac{1}{8}$	99	$4\frac{11}{16}$	$\frac{43}{64}$	50	1	$\frac{29}{64}$	49
Average of each.....							$\frac{49}{64}$	$\frac{64}{128}$	$43\frac{25}{100}$

	Collar.	Wright's Collarless.
Average mileage for each $\frac{1}{64}$ inch vertical wear.....	$301\frac{71}{100}$ miles.	$919\frac{52}{100}$ miles.
Average mileage for each oz. of metal worn away.....	$202\frac{32}{100}$ "	$609\frac{61}{100}$ "
Cost per coach, per 100 miles run, for bearings.....	$7\frac{16}{100}$ cents.	$2\frac{20}{100}$ cents.
Loss per coach, per 100 miles run, in weight of bearings..	$3\frac{58}{100}$ ozs.	$1\frac{10}{100}$ ozs.

Based upon the above statements the difference in weight of bearings required and the cost of the same, at 32 cents per pound, for the past two years, on the Atlantic and Great Western Railway, would be as follows:

YEAR.	TOTAL CAR MILEAGE.	COLLAR JOUR. BEARING.		COLLARLESS JR. BEARING.		DIFFERENCE.	
		Lbs. R'q'd.	Cost.	Lbs. R'q'd.	Cost.	Lbs. R'q'd.	Cost.
1866	35,738,517	79,961	$25,588 34	24,564	$7,862 40	55,397	$17,725 84
1867	39,119,931	87,515	28,008 87	26,889	8,705 75	60,536	19,303 12

Chain Surveying.—Inaccessible Points.

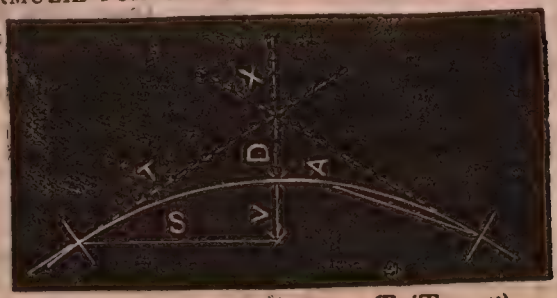


Measure off perpendiculars A C, D E, ranging the point C in line with E B

then $A\,B = \dfrac{A\,C \times A\,D}{D\,E - A\,C}$

For Trigonometrical Surveying, see Properties of Triangles, page

Formulæ for Setting Out Railway Curves.



R = Radius of curve.
T = Length of tangent.
x = Half angle of intersect'n.
D = Distance of centre of curve from intersection.
C = Any chord.
A = Tangential angle of C, in [minutes.

$R = \dfrac{1719\,C}{A}$

$R = T\ (\text{Tan. } x)$
$T = R\ (\text{Cotang } x)$.
$D = R\ (\text{Cosecant } x - 1)$.
$A = \dfrac{1719\,C}{R}$
$S = R\ (\text{Cosine } x)$.
$V = R\ (\text{Coversine } x)$.

Number of chords in the curve $= \frac{5400-x}{A}$

Length of the curve $= .000582\ R\ (5400-x)$.

Note.—x and A in the two preceding formulæ must be expressed in minutes.

TABLE OF TANGENTIAL ANGLES FOR 1 CHAIN CHORDS.

Radius of Curve Chains.	Tangential Angle.	Radius of Curve Chains.	Tangential Angle.	Radius of Curve Chains.	Tangential Angle.	Radius of Curve.	Tangential Angle.
5	5° 43.8	15	1° 54.6	40	42′.97	1 mile.	21′.48
8	3 34.87	20	1 25.95	45	38.2	1¼ "	17.19
9	3 11.	25	1 8.76	50	34.38	1½ "	14.33
10	2 51.9	30	57.3	60	28.65	1¾ "	12.28
12	2 23.25	35	49.11	70	24.55	2 "	10.74

Note.—The angle for 2 chain chords is double the angle for 1 chain chords. The angle for ½ chain chords is ½ the angle for 1 chain chords.

Curves of less than 20 chains radius should be set out in ½ chain chords. Curves of more than 1 mile radius may be set out in 2 chain chords.

The angles in the above table are in degrees, minutes and decimals of minutes.

LEVELLING WITH THERMOMETER.

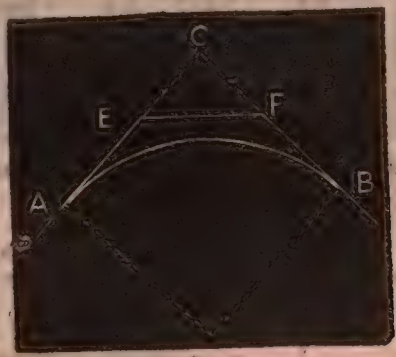
T = Temperature of boiling water at any station (in degrees Fahr.), deducted from 212°.

H = Height of the station above the level of the sea, in feet.

$H = 520\ T + T^2$.

Table of Tangential Angles for Chords of 1 Foot and 100 Feet.

Radius of Curve.	Angle of Deflection.		Radius of Curve.	Angle of Deflection.		Radius of Curve.	Angle of Deflection.	
	Chord 1 Foot.	Chord 100 Feet.		Chord 1 Foot.	Chord 100 Feet.		Chord 1 Foot.	Chord 100 Feet.
feet.	min.	d. m.	feet.	min.	d. m.	miles.	min.	d. m.
500	3.438	5 43.77	3000	0.573	0 57.30	⅛	2.604	4 20.44
600	2.865	4 46.48	3500	0.491	0 49.11	¼	1.302	2 10.22
700	2.456	4 5.55	4000	0.430	0 42.97	½	0.651	1 5.11
800	2.149	3 34.86	4500	0.381	0 38.20	¾	0.434	0 43.41
900	1.910	3 10.99	5000	0.344	0 34.38	1	0.326	0 32.55
1000	1.719	2 51.89	5500	0.313	0 31.25	1¼	0.260	0 26.04
1100	1.563	2 36.26	6000	0.286	0 28.65	1½	0.217	0 21.70
1200	1.432	2 23.24	7000	0.246	0 24.56	1¾	0.187	0 18.70
1500	1.146	1 54.59	8000	0.215	0 21.49	2	0.163	0 16.28
2000	0.859	1 25.94	9000	0.191	0 19.1	2½	0.130	0 13.02
2500	0.688	1 8.76	10000	0.172	0 17.19	3	0.109	0 10.85



When C is inaccessible, run any line EF, then

$$\angle CEF = 180^\circ - \angle AEF$$

also $\angle CFE = 180^\circ - \angle BFE$ therefore

$$\angle ACB = 180^\circ - (\angle CEF + \angle CFE)$$

and side $EC = \dfrac{EF \times \text{Sine} \angle CFE}{\text{Sin} \angle ACB}$

$$FC = \frac{EF \times \text{Sin} \angle CEF}{\text{Sin} \angle ACB}$$

For Ranging Curves by Offsets in Equal Chords.

$$\text{Offset } O = \frac{\text{Chord}^2}{\text{Radius}}$$

$$\text{Offset } x \text{ from tangent} = \frac{\text{Offset } O}{2}$$

$$= \frac{\text{Chord}^2}{2 \text{ Rad.}}$$

Measurement of Earthwork.

To measure the solidity over large areas of irregular depth, divide the surface into triangles, and multiply the area of each

by one-third of the sum of the depths taken at the angles, and the result will equal the solidity.

Rules for the Versed Sines and Ordinates of Curves.

Versed sine $V = R - \sqrt{R^2 - (\frac{1}{2}C)^2}$

Diameter of circle $D = \frac{(\frac{1}{2}C)^2}{V} + V$

Length of ordinate $O = \sqrt{R^2 - X^2} - (R - V)$

Relative Value of Useful Angles to Angle of Intersection.

Let x = half the angle of intersection.

Then $A = 90^\circ - x$

$B = 90^\circ - x$

$C = 90^\circ + x$

$D = 90^\circ + x$

$E + F = 90^\circ - x$

$G + H = 90^\circ + x$

Measurement of Heights.

$$CB = \tan BAC \times AB$$

$$CD = \frac{AB}{\text{Cotan } CAD - \text{Cotan } CBD}$$

To Measure Heights with the Sextant.

Multiplier.	Angle.	Divisor.	Angle.	Multiplier.	Angle.	Divisor.	Angle.
1	45° 0′	1	45° 0′	5	78° 41′	5	11° 19′
2	63 26	2	26 34	6	80 32	6	9 28
3	71 34	3	18 26	8	82 52	8	7 8
4	75 58	4	14 22	10	84 17	10	5 43

Set the sextant to any angle in the table, height will equal the distance multiplied or divided, as the case may be, by the number opposite to it.

To find the distance in feet, when the angle, subtended by 1 foot at that distance, is known.

$$\text{Dist.} = \frac{3437 \cdot 7}{A}$$ A being the angle in minutes.

MANSFIELD ELASTIC FROG.

In a paper read before the Institution of Civil Engineers, by Mr. Price Williams, on the Maintenance and Renewal of Permanent Way, it was clearly shown by his experience, that a more liberal use of rails of better quality, and an ELASTIC ROAD BED, were necessary, and "on roads which had to sustain the heavy loads and great speeds of the main lines, the employment of timber was unavoidable." The annexed cut shows an Elastic Frog, the combination being as follows:

Explanation.

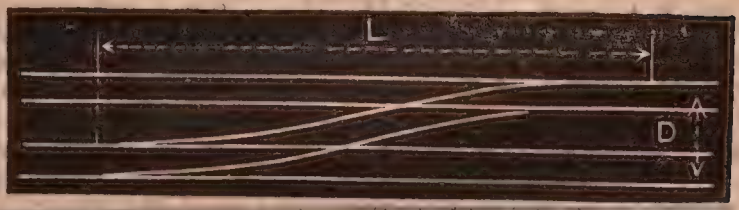
No. 1—Steel Point and Rails.
No. 2—Iron or Steel Heel.
No. 3—Wrought Iron Plate.
No. 4—Oak Plank.
No. 5—Pure Rubber.

No. 1—	Length 7 ft.	7 in.,	Angle	1 3-16	$140 00
No. 2—	" 5 "	9 "	"	1 1-2	115 00
No. 3—	" 5 "		"	1 11-16	105 00
No. 4—	" 4 "	6 "	"	1 15-16	100 00
No. 5—	" 4 "		"	2 1-8	95 00
No. 6—	" 3 "	8½ "	"	2 7-16	90 00

Being formed of steel, boiler plate, wood, and rubber, they combine DURABILITY, SAFETY, and ELASTICITY. In practice, the jar usual in passing over rigid frogs of steel or iron is entirely removed, which relieves the passing machinery from this most frequent cause of broken wheels and damaged equipment. Its effects are similar to that produced by a sledge upon a bar of iron placed upon a yielding substance, as compared with the effect produced when the bar is placed upon an anvil: in one case the blow is harmless; in the other, either the bar must flatten or the sledge recoil. The wear of these frogs is found

to be many times that of the ordinary cast-iron frog, and their cost not more than double. They are in use on the principal railways in the country. In ordering Frogs, a templet or drawing of it, the angle required; and when special orders are given for Crossing Frogs, full drawings must be sent to Mansfield Elastic Frog Co., Jas. H. Hoyt, President, New Haven, Conn.

Railway Sidings, etc.



R = radius of curve; L = length over points; D = distance between centre of lines of siding.

$$L = {}^{2}\sqrt{D.R - (\tfrac{1}{2}D)^2}$$

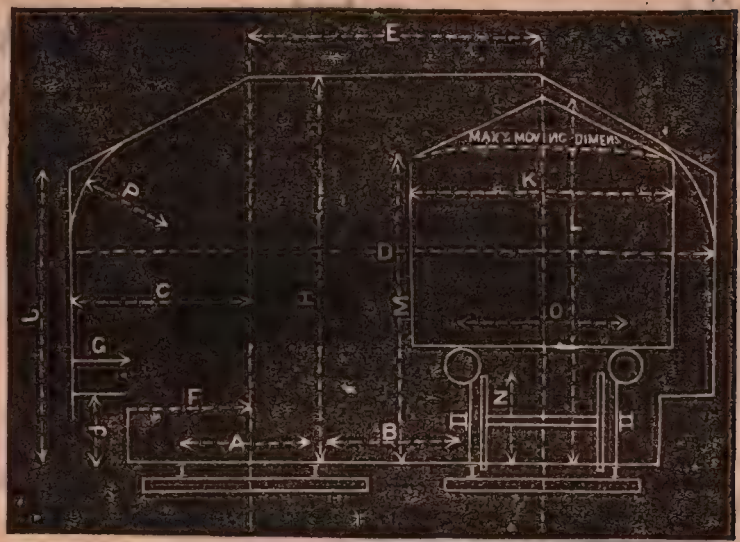
Frogs.

Length for Different Degrees.

°		Ft.	Ins.	°		Ft.	Ins.
5	Frog—Length.....	5	8¾	8	Frog—Length ...	3	7¾
5½	" "	5	2½	8½	" " ...	3	4½
6	" "	4	9¼	9	" "	3	2¼
6½	" "	4	4¾	9½	" "	3	0¼
7	" "	4	1¾	10	" " ...	2	10¼
7½	" "	3	9¾				

Ramapo Wheel and Foundry Co.

Gauge of Railways.



GAUGE.	A	B	C	D	E	F	G	H
Broad ..	7.0¾	6.0	7.0	27.5	13.5	5.7¼	1.4¾	16.0
Narrow.	4.8½	6.0	6.7	24.3¾	11.1¾	4.7	2.0	14.6
Irish ...	5.3	6.0	8.2	28.0	11.8	....	...	14.6
Indian ..	5.6	6.0	6.11½	24.10	11.11	5.2½	1.9	14.6
Prussian	4.8½	6.2¼	6.7	24.6	11.4	5.5	1.2	15.9

GAUGE.	I	J	K	L	M	N	O	P
Broad ..	14.0	2.9	9.6	14.3	11.7	3.1	5.10	6.0
Narrow.	11.0	2.0	8.4	13.6	11.7	3.4	5.8	2.0
Irish ...	10.6	...	....	....	....	...	...	8 0
Indian ..	11.6	3.0	10.6	13.6	11.6	3.6	6.5	3.0
Prussian	15.9	2.6	8.7	13.6	12.0	3.5	5.9	6.7

Cross Ties.

The usual dimensions of cross ties are—9 ft. long, 10 ins. wide × 5 ins.; average life-time, 7 years. They should be sound and well seasoned; seasoned white oak the best, should be laid on curves; a seasoned white oak tie holds a spike with twice the force, and seasoned locust 2½ times the force of green chestnut. The absolute retaining force of unseasoned chestnut on square or flat spikes, 2 to 4 ins. long, is 830 lbs. for every square inch of the two faces which condense longitudinally the fibres of the timber. The annual decay of wooden ties per mile of double track in England was $514. If timbers were preserved the duration is 15 years; annual cost lessened to $300 per mile.

On Reading R. R., in 1867, average cost of Burnettizing 91,898 ties was 10 68-100 cents per tie; average number of ties used per mile per annum, 344. On Pennsylvania R. R., average number of ties used per annum for renewals in 1867, were 312 per mile, or 11.81 per cent. of total, placing the ties at 2 feet centres.

The cost in England of wooden ties per mile being $550, the cost of iron permanent way would be from $5,000 to $9,000 per mile in U. S.

Methods of Preserving Timber are—

Creosoting—By coal oil, or common coal tar deprived of its ammoniacal liquor by boiling.

Boucherie Process—Solution of 1 lb. salts of sulphate of copper (blue vitriol) to 12½ galls. of water.

Kyanizing—1 lb. bi-chloride of mercury (corrosive sublimate) to 15 galls. of water.

Burnettizing—1 lb. chloride of zinc to 8½ galls. of water, or 1½ to 100 by weight.

Payne's Process—Green vitriol (or copperas), forced into the timber, followed by solution of chloride of lime.

Rules for the Weight of Rails.

W = weight of rail, in pounds, per yard.
L = greatest load on one driving-wheel, in tons.
W = L × 2.

Sectional area of rail, in inches × 10.08 = weight of rail, in pounds, per yard. Weight of rails, per yard × 1.571 = weight of rails, in tons, for a mile of single line of railway.

Ramapo Wheel and Foundry Co.

WEIGHT OF RAILS PER MILE.

THE SECTIONAL AREA—WEIGHT PER YARD—WEIGHT PER MILE OF SINGLE TRACK.

Area in inches.	Weight per yard in lbs.	Tons, 2,240 lbs. per mile.		
		Tons.	Cwts.	Lbs.
5	50	78	11	48
5¼	52	81	14	32
5½	55	86	8	64
5¾	56	88	..	..
6	60	94	5	80
6½	64	100	11	48
7	70	110	..	..
7½	75	117	17	16
8	80	125	14	32
9	90	141	8	64
10	100	157	3	84

No. of 15 ft. rails per mile, 704 | No. of 18 ft. rails per mile, 587
" 16 " " 660 | " 20 " " 528

BALLAST.

CUBIC YARDS PER MILE OF BALLAST.

Depth of Ballast in inches.	SIDE SLOPE OF BALLAST 1 TO 1. WIDTH IN FEET.					
	Single Track.			Double Track.		
	10	11	12	21	22	23
12	2.151	2.347	2.543	3.303	4.499	4.694
18	3.373	3.667	3.961	6.601	6.895	7.188
24	4.700	5.085	5.477	8.997	9.389	9.780
30	6.111	6.601	7.090	11.491	11.980	12.469

Cross Ties.

No. per mile,	2	feet centre to centre	.....	2,641
" "	2¼	" " "	.....	2,348
" "	2½	" " "	.....	2,113
" "	2¾	" " "	.....	1,921
" "	3	" " "	.....	1,761

Railway Curves.

DEGREE.	RADIUS.	VERS. SINE.
1 deg.	5,730 feet.	1-8 inch.
2 "	2,865 "	3-16 "
3 "	1,910 "	5-16 "
4 "	1,432 "	7-16 "
5 "	1,146 "	1-2 "
6 "	955 "	5-8 "
7 "	819 "	3-4 "
8 "	716 "	13-16 "
9 "	637 "	15-16 "
10 "	573 "	1 1-16 "
11 "	521 "	1 1-8 "
12 "	478 "	1 1-4 "
13 "	441 "	1 3-8 "
14 "	410 "	1 7-16 "
15 "	383 "	1 9-16 "
16 "	359 "	1 11-16 "
17 "	338 "	1 3-4 "
18 "	319 "	1 7-8 "
19 "	302 "	2 "
20 "	287 "	2 1-16 "

The radius of a 1 degree curve equals about 1 1-12 miles. That of any other degree is found by dividing 1 1-12 miles, or 5,730 feet, by the number of degrees.

Example—Radius 6° curve = 5,730 ÷ 6 = 955 feet.

Curvature of the earth is equal 8 inches per statute mile.

Ramapo Wheel and Foundry Co.

Super-elevation of Outer Rails on Curves.

Super-elevation in inches is found by multiplying the gauge in feet by the square of the velocity in miles per hour; and dividing the product by the radius of the curve in chains, and by 397.5.

The less the radius of curvature, and the greater the speed, the greater is the elevation of the outer rail upon a curve.

Radius of curve in feet being	Elevation of the Outer Rail in inches; the velocity in miles per hour being		
	10	20	30
500	0.57	2.83	6.56
1,000	0.29	1.43	3.30
2,000	0.15	0.71	1.65
3,000	0.10	0.47	1.10
4,000	0.07	0.36	0.83
5,000	0.06	0.28	0.66

The Bending of Rails.

Each rail, in a curved track, requires to be bent to fit that curve before being laid. This may be done by placing the ends of the rails upon supports, and pounding the rail until a "straight edge" shows the proper amount of curvature to be attained; or by pressure applied to the rail in a straightening or bending machine. The versed sine of curvature at the middle of the rail, for different radii of curvature and for different lengths of rails, are given below.

Radius of Curvature and Versed Sines for Rails.

Radius of curvature in feet.	Versed Sines for Rails, the length in feet being			
	15	16	18	20
286	1 3-16	1 5-16	1 11-16	2 1-16
301	1 1-8	1 1-4	1 5-8	2
318	1 1-16	1 3-16	1 1-2	1 7-8
337	1	1 1-8	1 7-16	1 3-4
358	15-16	1 1-16	1 3-8	1 11-16
382	7-8	1	1 1-4	1 9-16
409	13-16	15-16	1 3-16	1 7-16
441	3-4	7-8	1 1-8	1 3-8
477	11-16	13-16	1	1 1-4
521	5-8	3-4	15-16	1 1-8
573	9-16	11-16	7-8	1 1-16
636	1-2	5-8	3-4	15-16
716	1-2	9-16	11-16	13-16
818	7-16	1-2	9-16	3-4
955	3-8	3-8	1-2	5-8
1,146	5-16	5-16	7-16	1-2
1,432	1-4	1-4	5-16	7-16
1,910	3-16	3-16	1-4	5-16
2,865	1-8	1-8	3-16	3-16
5,730	1-16	1-16	1-16	1-8

The above radii are those corresponding (commencing at the top) to angles of defection from 20 to 1 deg. The versed sines are expressed in inches and fractions.

Frogs and Switches.

In laying down a frog, the problem to be solved by the track-layer is—how far from the heel of the switch rail to place the point of the frog. This distance depends upon the gauge, the

angle of the frog, and the movement of the switch rail. Frogs are usually made six inches across the head, and three inches of opening at the mouth; with these dimensions, we have the following distances in feet and decimals, the gauge being 4 feet 8½ inches, and the switch rail moving five inches at the toe.

Length of frog in feet.	Distance from toe of switch to point of frog, length of switch rail in feet being					
	12	14	16	18	20	22
3	29.1	29.7	30.1	30 4	30.7	30.9
3½	33.3	34.0	34 5	35 0	35.3	35.6
4	37.3	38.2	38.8	39 4	39.8	40.2
4½	41.1	42.2	43.0	43.7	44.3	44.7
5	44.8	46 1	47 1	47.9	48.5	49.1
5½	48.3	49.0	51 0	51.9	52.7	53.2
6	51 7	53 1	54.8	55.9	56 8	57.6
6½	55.0	56.9	58.5	59.8	60.8	61.7
7	58 1	60 3	62.1	63.4	64.7	65 7
7½	61.2	63.6	65.6	67.2	68.5	69.6

METHOD OF LAYING OUT A DIAGRAM, SHOWING POSITION OF TRAINS—FROM WHICH TO MAKE A TIME-TABLE FOR A RAILROAD.

From a point representing the first station on the road erect a perpendicular line, and, with a scale of equal parts, set off the total length of the road, and the position of all stations, marking the distance in miles between each station, and distance from starting point to each station. From the first and last station, and each intermediate station, draw horizontal lines, divide them into twenty-four equal parts, representing twenty-four hours; subdivide each part into six equal parts, representing ten minutes each; from these points erect perpendicular lines, which

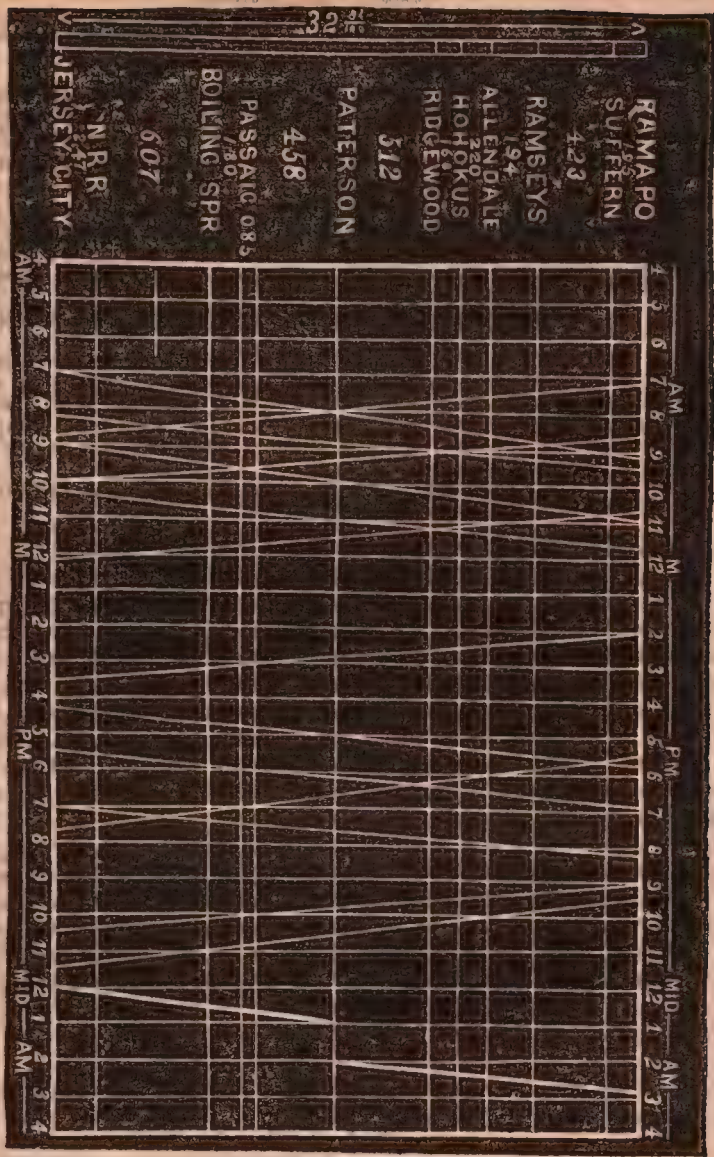


DIAGRAM OF TIME TABLE.

Ramapo Wheel and Foundry Co.

will intersect the station lines, designate each hour line with its appropriate hour, A. M., M., P. M., Mid., and A. M.

To Arrange the Trains.

Time of starting being fixed, and speed per hour in miles, to find time of arrival at a given station, divide the distance in miles by speed of train per hour or minutes. From the starting station at point representing time of starting, draw a line to the arrival station to point representing time of arrival.

The point of intersection of the line so drawn with station and hour lines, will denote time of arrival of train at each station, and position at any desired moment. The outgoing trains are designated by lines drawn from left to right. Incoming trains by lines from right to left; points of passing or meeting of trains by the intersection of these lines. An inspection of the accompanying diagram, taken from the Erie Railway Company, will readily explain the method. By this means a complete chart of the movements of all trains on a railway can readily be laid down.

Tools to be Carried on each Train.

Conductors should have on each Train—

12 detonating signals, 1 monkey wrench, 1 axe, 1 saw, a few spikes, 2 red flags, 2 clear and 2 hand signal lamps, 2 red tail lamps or red side lamps, 6 links and pins, 1 tail rope, can of oil, supply of wick, waste, and spare bell-rope. A medicine chest is required to be carried on some roads.

Engineers should have on each Locomotive—

1 hand signal lamp, 1 complete set of keys, extra bolts, nuts, and washers, 1 large and 1 small monkey wrench, 3 cold chisels, 1 hand hammer, 1 hand saw, 1 axe, 2 shovels, 1 pinch bar with spike claw, 2 large screw jacks, 2 small do. for journal boxes, 1 large chain or tail rope, 2 links and 2 pins, 1 pair of tongs, large and small plugs for tubes, 1 iron mandril for driving tubes, a few iron tube ferrules, flax gaskins and strings for packing, oil cans, 2 red flags, 2 or more fire buckets, 1 portable frog for putting cars on track, emery box, hose and pipe, waste, cooling mixture for journals, 2 extra journal brasses.

TELEGRAPH.

History of the Telegraph.

Soon after the discovery of the Leyden Jar, in 1747, it was observed that the shock passed through twelve thousand feet of wire, affected persons placed at either extremity, apparently at the same time, and the idea of instantaneous passage of electricity being received, led to investigations, which have been continued by all succeeding electricians.

In 1794 Reisen proposed a telegraph, employing the spark with seventy-six wires, or thirty-six complete circuits, one for each letter or number.

In 1798 a telegraph was built between Madrid and Arranjuez, a distance of twenty-six miles, by Betancourt.

In 1800 the Voltaic Battery was discovered.

In 1809 Soemmering improved this discovery by inventing a telegraph which indicated the letters by decomposition of water; he also caused the liberation of the gases to raise a cup attached to a lever, which caused a bell to ring.

In 1816 Dr. J. R. Coxe confidently predicted the success of the telegraph.

In 1819 Œrsted discovered the deflection of the compass needle.

In 1820 Ampère discovered the electro-magnet, by which a piece of soft iron, placed in the axis or centre of a coil of wire, becomes a magnet during the passage of a galvanic current through the coil.

In 1820–22 Ampère proposed and described the use of the deflection of a number of needles to constitute a telegraph similar to that of Wheatstone, now in operation in England, with a less number of circuits.

In 1826 the first registering telegraph was constructed by Mr. Harrison Gray Dyer, of Long Island, who used the decomposing power of the spark acting on litmus paper, moved by hand or clock work. This appears to have been the origin of the system of telegraphic alphabets so generally used in later inventions.

In 1832 the deflective telegraph was introduced into Russia by Schilling.

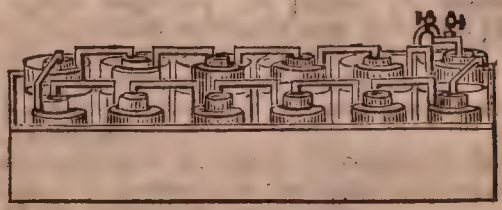
In 1833 Gauss & Heber introduced it into Gottingen.

In 1837 Wheatstone introduced it into England.

In 1837 Steinhill had in operation on the line between Munich and Bogenhausen, the first *electro-magnetic* telegraph which employed a registering apparatus, the deflection of the needles carrying pen points, which marked dots on paper moved by clock work, as had been done by common electricity by Dyer, and subsequently by Morse, in the United States.

In 1844 Professor S. F. B. Morse introduced the first really successful magnetic telegraph, on the line between Baltimore and Washington, being the realization of suggestions made by him in 1832, and to Professor Morse is conceded the successful introduction of the telegraph.

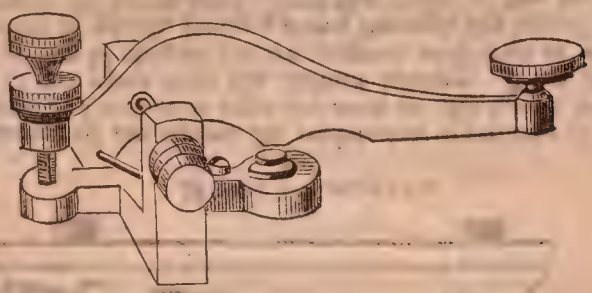
Description of the Telegraph.



GROVE'S BATTERY.

The cut represents a series of Grove's Battery, such as are generally used in telegraphs. When a plate of platina and one of zinc are placed in an acid solution a current tends to flow from the platina to the zinc, through any conductor which may be so disposed as to connect the two. In the figure the galvanic series is represented, consisting of twelve pairs; the zinc of each of which is connected with the platina of the next. It may be considered that a current is produced by each of these

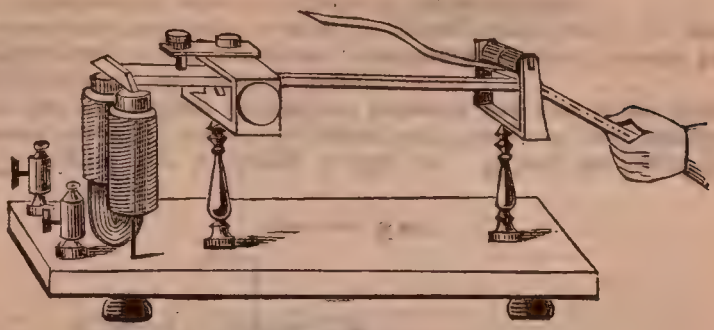
pairs, which has, however, to flow in the same direction, and fall in with all the others. Hence their intensity is multipled twelve times. It is by this means that the resistance to the passage of the current through very long conductors is overcome. Each pair of the battery consists of a pint glass tumbler, a cylinder of zinc, a small porous cylindrical earthenware cell within the zinc, and a platinum strip suspended within the cell from an arm belonging to the zinc of the next pair. A solution of diluted sulphuric acid is used with the zinc outside the porous cell, and the cell itself is filled with nitric acid. The two acids are used on account of an increase of power depending on a chemical reaction. The zinc cylinder is amalgamated with mercury to prevent its being acted upon by the acid when the battery is not in use. A solution of sulphate of soda is sometimes added to the sulphuric acid to assist in accomplishing the same object. Two screw cups rise from the battery, one of which is the positive pole, or extremity of the series, the other the negative; to these the wires are attached which convey the current.



SIGNAL KEY.

The signal key is shown in the cut. When the hand depresses the key it comes in contact with the knob and metallic strip below, making connection between the two screw cups, and completing the battery circuit.

While the key is depressed a continuous current passes, but if it be depressed, and allowed to spring immediately up, only an instantaneous wave or impulse is communicated.



MORSE'S REGISTER.

The annexed cut shows the registering apparatus of Morse's Telegraph. Two screw cups are seen on the board for the insertion of the wires from the distant battery. Next the screw cups is seen a U shaped electro-magnet, with coils of wire upon it, the ends of which, passing down through the board, are connected with the screw cups; over the poles of the magnet is a little armature, or bar of soft iron, attached to the short arm of a lever, whose long arm carries a point or style nearly in contact with the grooved roller above. The action which takes place on depressing the signal key at the distant station is, a wave of electricity is transmitted through the wire of the telegraph, arrives at the electro-magnet, and circulates through the coils of wire surrounding it. The U shaped soft piece of iron immediately becomes a magnet, and attracts the little armature down to it, the long arm of the lever is thrown up, and marks the strip of paper, passing between it and the roller. When the distant operator lets the signal key fly back and the current ceases, the iron of the electro-magnet loses all its magnetism, and the armature, with the lever, is carried back by the action of a little spring, being a *dot* impressed on a strip of paper; Should the distant operator hold down the key a continuous current will pass, and a line be marked in place of a dot (–) on the paper which moves under the roller.

When a long circuit is used, the resistance to conduction, measured by the amount of electricity which passes, is great,

and would not give sufficient force to work the Morse instruments. To overcome this, Professor Morse uses an instrument called a *Relay*, which is similar in most respects to the main instrument, but of a more delicate electrical organization; it has no work to do—simply acting as a contact maker, enabling a weak or exhausted current to bring into action and substitute for itself a fresh and powerful one from the local battery which is placed in the office with the printing instrument, and which supplies the electricity which moves the instrument.

The greatest recorded velocity of a signal through a suspended copper wire is 1,752,800 miles per second, by Mr. Hipp. The lowest velocity through a buried copper wire, 750 miles per second, by Faraday.

Morse's Alphabet, Numerals, and Pauses.

Alphabet.

A - —	J — - — -	S - - -
B — - - -	K — - —	T —
C - - -	L — —	U - - —
D — -	M — —	V - - - —
E -	N — -	W - — —
F - — -	O - -	X - — - -
G — — -	P - - - - -	Y - - - -
H - - - -	Q - - — -	Z - - - -
I - -	R - - -	& - - - -

Numerals.

1 - — — -	5 — — —	8 — - - - -
2 - - — -	6 - - - - - -	9 — - - —
3 - - - — -	7 — — - -	0 — — — — —
4 - - - - —		

Pauses.

Period, - - — — - -	*Emphasis, — - - - —
Semi-colon, - — - — -	*Parenthesis, - — - - —
Exclamation, — - — — -	Comma, - — - —
*Quotation, - — - — - — - —	Interrogation, — - - — -

* To be used before and after the words to which they are to apply.

Ramapo Wheel and Foundry Co.

Hints to Learners.

*Compiled from Modern Practice of the Electric Telegraph, by Frank L. Hope.**

The characters of the American Morse Alphabet are formed of three elementary signals—

The *dot*, whose duration is the unit of length in this alphabet;
The *short dash*, which is equal to *three dots;* and
The *long dash*, which is equal to *six dots.*

The above are separated by variable intervals or *spaces*, four in number:

1st—The ordinary *space* between the elements of a letter, equal to *one dot.*

2d—The *space* employed in the *spaced letters*, equal to *two dots.*

3d—The space between the letters of a word, equal to *three dots.*

4th—The space between *two* words, equal to *six dots.*

The dot signifies a point or a current of infinitely short duration, and involves *time*, which varies according to circumstances, the length of the dot increasing with the length of the circuit.

In long submarine lines the dot has to be made longer than the dash itself on short open air lines, and the same thing occurs in working through repeaters.

In commencing to learn telegraphing, the beginner should acquire the habit of making short, firm *dashes*, instead of light, quick *dots.*

In the valuable Manual of Prof. Smith, published by L. G. Tillotson & Co., New York, six elementary principles are laid down as the basis for practising the alphabet, viz.:

1st Principle—Dots close together:

I S H P 6

2d Principle—Dashes close together:

M 5 ¶

— — — — — — — — —

* Russell Bros., Publishers, 23 to 32 Centre street, New York.

3D PRINCIPLE—Lone dots:

E

4TH PRINCIPLE—Lone dashes:

T L or cipher.

5TH PRINCIPLE—A dot followed by a dash:

A

6TH PRINCIPLE—A dash followed by a dot:

N

To send messages, place the first two fingers upon the top of the button of the key, with the thumb partly beneath it, the wrist being entirely free from the table; the motion being made by the hand and wrist, the thumb and fingers being employed merely to grasp the key. The motion up and down must be free and firm. TAPPING on the key must be strenuously avoided.

The *downward* movement of the key produces *dots* and *dashes;* the upward movement, *spaces.*

The beginner should first practise the 1st principle, making *dots* at regular intervals, of definite and uniform dimensions.

2d Principle—Make dashes, first at the rate of one per second, and slowly increase to three, the space between the dashes to be as short as possible.

3d Principle—Letter E, formed by a quick, but firm, downward movement of the key.

4th—The usual tendency is to make T too long and L too short. The same character is used for L and the cipher, or 0; occurring by itself, or among letters, it is translated as L; when found among figures becomes 0.

5th—The letter A may be timed by the pronunciation of the word *again*, strongly accenting the second syllable.

6th—The dash followed by a dot; usually the student separates the dot from the dash by too great a space; movement

can be timed by pronouncing the word *ninety*, the first syllable somewhat longer than usual.

Having become thoroughly conversant with the six elementary principles, practise the following exercises:

(1) E I S H P 6

(2) T M 5 ¶ L or cipher.

(3) A U V 4

(4) H V P 4

I A S U

(5) N D B 8

(6) A F X Parenthesis.

Comma. Semicolon. W I

(7) U Q 2 Period. 3

(8) K J 9 Interrogation.

G 7 Exclamation.

J and K are generally considered the most difficult letters in the alphabet. Do not separate J into double N. The dashes must in all cases correspond in length.

(9)—Spaced letters:

O R & C Z Y

The space should be exactly double that ordinarily used between the elements of a letter.

READING BY SOUND can only be attained by constant and

persevering practice. The lever of the Morse instrument makes a sound at each movement, the downward motion producing the heavier one, or that representing dots and dashes; *i. e.*, the heavy stroke indicates the commencement of a dot or dash, and the lighter one its cessation. A dot makes as much noise as a dash, the only difference being in the length of time between the two sounds.

Technical Terms used in the Telegraph Service.

Line.—The wire or wires connecting one station with another.

Circuit.—The wires, instruments, etc., through which the current passes from one pole of the battery to the other.

Metallic Circuit.—A circuit in which a return wire is used in place of the earth.

Local Circuit.—One which includes only the apparatus in an office, and is closed by a relay.

Local.—The battery of a local circuit.

Loop.—A wire going out and returning to the same point, as to a branch office, and forming part of a main circuit.

Binding Screws or *Terminals.*—Screws attached to instruments holding the connecting wires.

To Cross Connect Wires.—To interchange them at an intermediate station.

To Put Wires Straight.—To restore the usual arrangement of wires and instruments.

To Ground a Wire, or *Put on Ground.*—To make a connection between the line wire and the earth.

To Open a Wire.—To disconnect it so that no current can pass.

Reversed Batteries.—Two batteries in the same circuit, with like poles towards each other.

To Reverse a Battery.—To place its opposite pole to the line; or, in other words, interchange the ground and line wires at the poles of the battery.

Escape.—The leakage of current from the line to the ground, caused by defective insulation and contact with partial conductors.

Cross.—A metallic connection between two wires, arising from their coming in contact with each other, or from other causes.

WHAT THE LOCOMOTIVE HAS ACCOMPLISHED.

In 40 years the miles of railway of the United States have increased from 3 miles to 60,000 miles.

Up to 1865, during the 41 years which have elapsed since the first railway was laid down in England, $2,500,000,000 have been invested in railway capital, and the various lines now in operation measure 13,289 miles in length. In 1865, on the various roads, 3,448,509 passenger trains, carrying 251,862,715 passengers, travelled 71,203,818 miles, while 2,108,198 freight trains transported 15,179,000 horses, dogs, cattle, and other stock, 77,805,780 tons of minerals, and 36,787,638 tons of general merchandise, over 68,320,309 miles. These passenger and freight trains together travelled in one year as great a distance as from the earth to the sun and one-half the way back. In order to do this business, the company had to keep a rolling stock of 7,414 locomotives, 17,997 passenger cars, and 233,260 freight cars and trucks. The receipts during the year were $179,450,000, the expenses $86,055,000, and the balance of profits of the companies during the year were $93,395,000. In 1866 the passengers carried were 313,699,268, or an average of 10 journeys by rail yearly for every man, woman, and child in Great Britain, employing 19,228 vehicles, which ran 73,383,356 miles in 3,741,086 trains, hauled by 8,125 locomotives, or 2 engines for every 3 miles open, hauling 6,000,000 of trains a distance of 143,000,000 of miles. The average earning of each locomotive was $25,000 yearly, or $1.25 a train mile.

A SHORT HISTORY OF THE LOCOMOTIVE.

As early as two hundred years B. C., Hero, of Alexandria, in his book, Spiritalia seu Pneumatica, treated of the expansive force of steam, described the slide valve, the spindle valve, and illustrated the use of a metallic piston to a metallic cylinder.

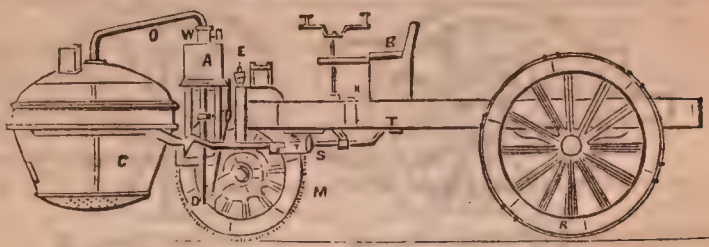
A. D. 1640.—Solomon de Caius included land transport by steam as a possible result.

1759.—Robinson suggested to James Watt that the power of steam could be made to drive land carriages.

1769.—The first self-moving locomotive engine was made by a Frenchman, Nicholas oseph Cugnot.

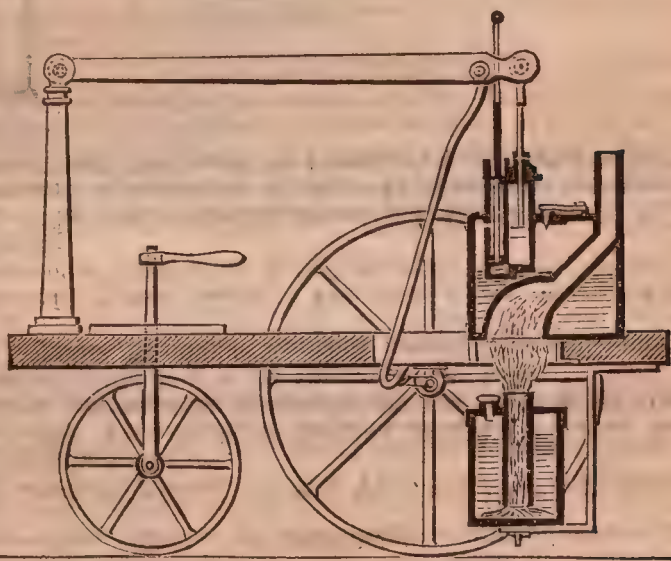
1771.—A locomotive was made by Cugnot for the French Government, and now in their possession. It has 13-inch single-acting cylinders, copper boiler, single driving-wheels, 4 feet 2 inches diameter, 7 inches face.

HISTORY OF THE LOCOMOTIVE—Continued.



CUGNOT'S LOCOMOTIVE.

1784.—Watt specified devices for giving motion to wheeled carriages, and a working model was made by Mr. Murdock, foreman for Mr. Watt, in 1784.



MURDOCK'S LOCOMOTIVE.

Ramapo Wheel and Foundry Co.

HISTORY OF THE LOCOMOTIVE—Continued.

1787.—Oliver Evans, of Philadelphia, applied steam to a wagon.

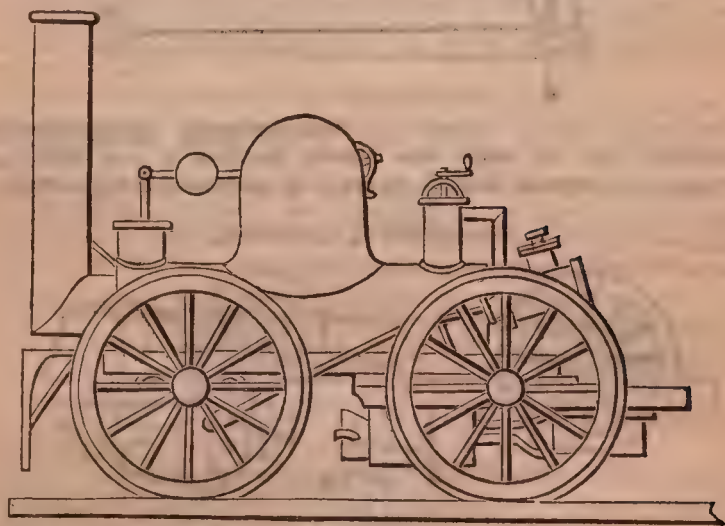
1803.—John C. Stevens, of New York, invented and patented the water-tube boiler.

1804.—Mr. Trevethick, of England, obtained a patent for a locomotive, and was the inventor of the use of the waste steam for promoting the draft in the furnace of the boiler.

1826.—James Neville, of England, invented the multi-tubular boiler.

1828.—Mr James Seguin, a French engineer, suggested the employment of small tubes to convey smoke from the furnace to the chimney.

1829.—The trial on the Liverpool and Manchester R. R., of Stephenson's Locomotive Rocket, Hackworth's Locomotive Sanspareil, and Braithwaite & Ericsson's Locomotive Novelty, took place.



DEWITT CLINTON.

HISTORY OF THE LOCOMOTIVE—Continued.

First engines used in the United States were built in England, by Robert Stephenson and John M. Rastric; were used on the Delaware and Hudson Canal in 1829; were unsuccessful, and, after running a few weeks, were abandoned.

The first successful and permanent type of the modern locomotive was made by Edward Bury, in the Locomotive Liverpool, at Liverpool, in 1830. Springs were applied to locomotives in 1830, by T. Hackworth. The first successful locomotive built in the United States was the Locomotive DeWitt Clinton, built by the West Point Foundry, New York city, to run on the Mohawk and Hudson R. R.; trial trip took place July, 1831.

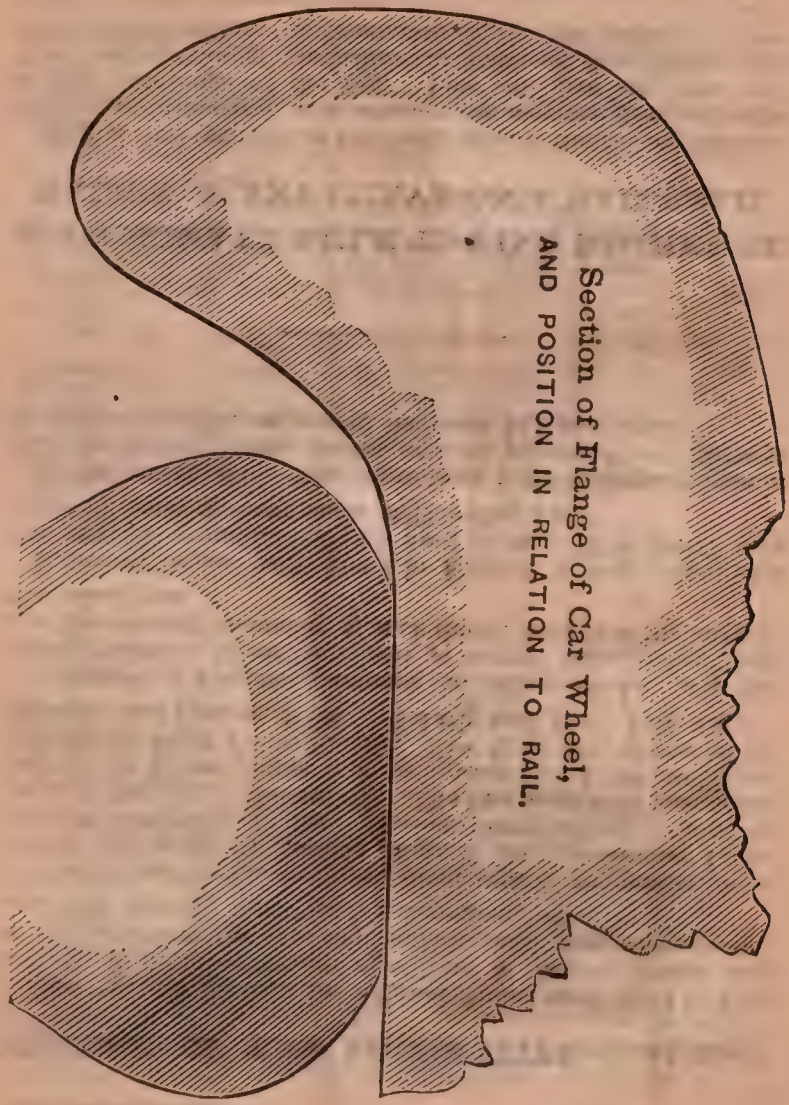
Cylinders, 5½ inches diameter, 16 inches stroke; 4½ feet driving wheels; boiler contained 30 copper tubes, 5 feet long, 4 inches external diameter, ¼ inch thick; weight of the locomotive was 4 tons.

Railways for coal were in use in England in 1650; shod with iron in 1760; wrought iron rails used in 1805. The first T rails rolled in America, were made at Danville, Pa.

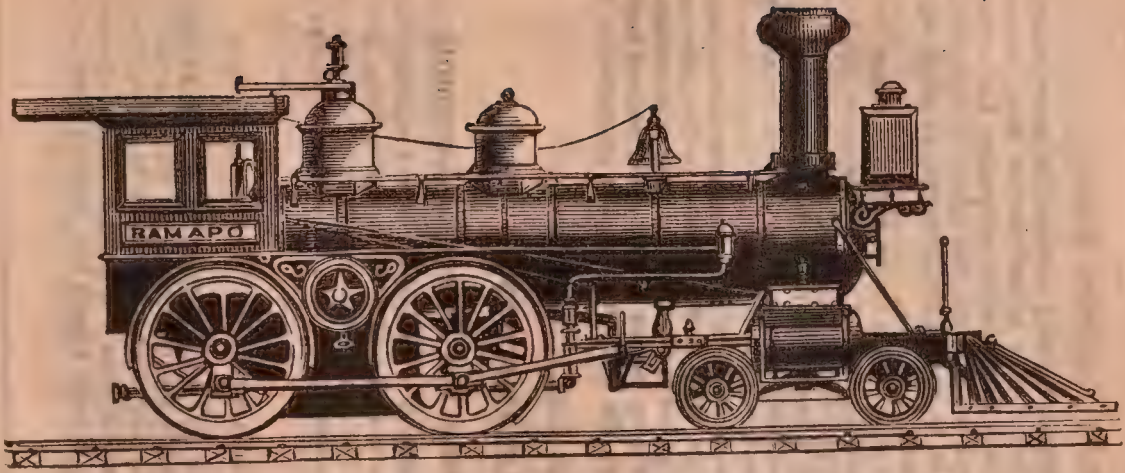
At the present date, 1867, more than 7,500 locomotives are in daily use in the United States, on over 37,000 miles of railway, of which the capital expended has been $1,650,000,000.

APPROXIMATE RULE TO FIND DEGREE OR RADIUS OF ANY CURVE ON A RAILROAD.

Hold a cord (exactly 20 feet long) against the rail, on the concave side of the curve, and measure the distance from its centre to the same edge of the rail. This will give the vers sine. Find corresponding dimensions in Table of Vers Sines; the other column will give approximate degree and radius of curve.



Richmond Iron.



COAL LOCOMOTIVE OF 1867,

WITH HOLLOW SPOKE ENGINE AND TENDER WHEELS,

FROM

Ramapo Wheel and Foundry Co.,

Economy of Clothing Boilers.

A square foot of ordinary heating surface has about one-fifth the heat-transmitting power of a square foot of freely exposed cooling surface; or in any given boiler, supposing the areas of heating and cooling surface are equal, the effect of the latter, if freely exposed, would be to reduce the evaporative efficiency of the boiler twenty per cent.

The exposed surface of a boiler, or its cooling surface, in no way differs from its heating surface; it is subject to the same laws, and under similar circumstances produces similar effects. A square foot of cooling surface withdraws from the contents of a boiler a less amount of heat than is imparted to it by an equal area of heating surface—is merely due to there being a less difference between the temperature of the atmosphere and that of the contents of the boiler, than there is between the latter and the temperature of the gases in the flues. Other circumstances being equal, the transmitting power of any given area of boiler surface varies directly as the difference in the temperature on the two sides of it.

LOCOMOTIVE.

Rules for Calculating the Power of Locomotives.

The power of a locomotive is measured in the moving force at the tread of the tires, and is called the tractive force, and is equivalent to the load the locomotive could raise out of a pit, by means of a rope attached to the circumference of the tire on the driving-wheel.

Rule 1.—To Calculate the Tractive Power.

Multiply the diameter of the cylinder in inches by itself. Multiply the product by the mean pressure of steam in the cylinder in pounds per square inch. Multiply this product by length of stroke in inches; divide the product by the diameter of the wheel in inches. Result equals the tractive force at the rails.

Rule 2.—To Calculate Load which can be Hauled by an Engine on a Level at a Given Speed.

Divide the tractive force, as per Rule 1, by the resistance in pounds per ton due to friction, imperfection of road, and winds. The quotient is the total load in tons, comprising the engine, tender, and train.

Rule 3.—To Calculate Total Resistance of Engine, Tender, and Train, at a Given Speed, due to Friction, etc.

Square the speed in miles per hour, divide it by 171, and add 8 to the quotient. The result is the total resistance at the rails in pounds per ton weight.

Rule 4.—To find Load Locomotive can Haul at Given Speed on a Given Incline.

Divide the tractive power of the engine in pounds by the resistance due to gravity on given incline, added to resistance due to assumed velocity of train in pounds per ton. The quotient, less the weight of engine and tender, equals load in tons engine can haul on given incline.

Example—Rule 1.—What is the tractive force of a locomotive 16-in. cylinder, 24-in. stroke, 4 feet drivers, mean pressure 80 lbs. per square inch? $16 \times 16 \times 24 \times 80 = 491520 \div 48 = 10{,}240$ lbs. tractive force.

Example—Rule 2.—What load can a locomotive, 16-in. cylinder, 24-in. stroke, 4 feet drivers, mean pressure 80 lbs., haul on a level at 30 miles per hour? Tractive force 10,240 lbs. divided by ($30^2 \div 171 = 5.26 + 8 = 13.26$) resistance = 772¼ tons on a level.

Example—Rule 4.—What load can a locomotive, 16-in. cylinder, 24-in. stroke, 4 feet drivers, mean pressure 80 lbs., haul on a grade of 40 feet to the mile at 30 miles per hour?

Tractive force 10,240 lbs. divided by resistance due to gravity on incline of 40 feet to the mile, or 56 lbs. (see Table of Gradients) + 13.26 resistance = 10,240 ÷ 69.26 = 147.83 tons—less weight of engine and tender.

Table of Gradients.

Rise per mile, and Resistance due to Gravity alone.

Gradient of 1 inch...	20	25	30	35	40	45	50	60	70	80	90	100
Rise in feet per mile..	264	211	176	151	132	117	105	88	75	66	58	52
Resistance in lbs. per ton of train.....	112	89½	74¼	64	56	50	45	38	32	28	25	22

Resistance due to gravity on any incline in pounds per ton of train, equals 2,240, divided by rate of gradient.

Resistance of Trains, on a Level, at Different Speeds, in pounds per ton of load.

The resistance of curves may be reckoned as 1 per cent. for each degree of the curve occupied by the train.

Imperfections of road vary from 5 to 40 per cent.

Strong side winds..... 20 "

Velocity of train in miles per hour.	10	15	20	30	40	50	60	70
Resistance on straight line in lbs. per ton...	8½	9¼	10¼	13¼	17¼	22½	29	36½
Ditto, with sharp curves and strong wind,*...	13	14	15½	20	26	34	43½	55

* 50 per cent. added to resistance on straight line.

The power of an engine may be roughly computed by calling it equal to 1-6 of the weight on the driving wheels.

Adhesive Power of Locomotives per ton of load on the Driving Wheels.

When rails are dry	600	lbs. per ton.
" " " wet	550	" "
" " " damp	450	" "
Foggy weather	300	" "
Ice or snowy weather	200	" "

Rule 5.—To Calcultate Resistance of Train alone at a given Speed.

Square the speed in miles per hour, divide it by 240, and add 6 to the quotient. Result is the resistance at the rails in pounds per ton weight.

Rule 6.—To Calculate Resistance of the Engine and Tender alone with a Given Train at a Given Speed.

First find resistance as carriages by Rule 3, square the speed, and divide it by 600, and add 2 to the quotient, multiply the sum thus found by the total weight of engine, tender, and train, and divide by the weight of the engine and tender. The quotient expresses total machinery friction. Add the two results thus obtained, the sum is the whole resistance at the rails in pounds per ton weight.

Friction is a constant quantity at all speeds of about 8 lbs. per ton.

Friction of locomotives is about 9 per cent., or 2 lbs. per ton of weight.

Locomotive moving friction is 15 lbs. per ton.

The resistance to traction of a train on a level is doubled by a radius of curve of 400 feet, and 13 lbs. per ton is the additional friction upon a curve of 300 feet.

Friction of Railway Carriages.—The least resistance in parts of the weight, as determined by experiments, is the 1-288 part, and the greatest resistance 1-115 part, equal to a resistance of 7.48 lbs., and of 20.2 lbs. per ton; the average resistance of a great number of experiments being the 1-246 part, equal to 8.83 lbs. per ton.

The resistance to the leading car of a train is about 12 lbs. per ton, and of the intermediate cars about 8 lbs. The resistance of the atmosphere to a train is as the square of its velocity, being ½ lb. per square foot for a velocity of 10 miles per hour · 1 lb. for 20 miles per hour.

Resistance of Trains,

Determined by Experiments of Mr. Gooch, with a Dynamometer.

Engine and tender, 50 tons; train, 100 tons.

Velocity per hour.	Cars.	Resistance, in pounds, per ton.			
		Engine and Cars.	Engine and Tender.	Atmosphere for Cars.	Oscillation of Cars.
Miles.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
13.1	7.56	9.04	11.97	.62	.85
20.2	8.19	12.28	20.43	1.47	1.35
45.3	14.36	21.84	37.36	7.37	3.02
56.6	21.8	31.16	46.11	11.53	3 77
61.3	19.8	32.86	50.68	13.52	4.09

The atmospheric resistance for bulk of cars alone is estimated as equal to the product of .00002 the bulk of the cars in cubic feet, and their velocity in miles per hour, squared.

THE OSCILLATING RESISTANCE TO CARS ALONE is estimated at the quotient of the product of the weight of the cars, and their velocity in miles per hour, divided by 1 5.

THE RESISTANCE OF THE ENGINE AND TENDER ALONE is estimated by the sum of .5 the velocity in miles per hour, added to 5 for the friction of the axles and parts; to this sum add the product of .00004 times the square of the velocity and the weight of the cars, and multiply their sum by the weight of the engine and tender in tons.

Ex.—Assuming a train of 150 tons (engine and tender 50 tons, cars 100), at a velocity of 55 miles per hour, and a bulk of cars of 18,000 cubic feet.

Then $.00002 \times 18000 \times 55^2 = 1089$ lbs. *atmospheric resistance.*

$\frac{100 \times 55}{15} = 366.6$ lbs. *oscillating resistance.*

$55 \times .5 + 5 + 55^2 \times .00004 \times 100 \times 50 = 2230$ lbs. *eng. and tend.*

$100 \times 6 = 600$ lbs. *frict. of cars.*

4285.6 lbs.

Hence $\frac{4285.6}{150} = 28.57$ lbs. *per ton of the train.*

Experiment gave resistance of 29 lbs. per ton.

TO COMPUTE THE MAXIMUM LOAD AN ENGINE CAN DRAW UP THE MAXIMUM GRADE IT CAN ATTAIN, WEIGHT AND GRADE BEING GIVEN—(*Major McClellan, U. S. A.*)

$$\frac{.2\,A}{.4242\,G + 8} = L \text{ and } \frac{.2\,A - 8\,L}{.4242} = G.$$

A representing the adhesive weight of the engine in lbs.; G, grade in feet per mile, and L, load in tons.

Note.—When the rails are out of order, and slippery, etc., for .2 A put .143 A; with an engine of 4 drivers, put .6 as the weight resting upon the drivers; with 6 drivers, the entire weight rests upon them. The adhesion of a 4-wheeled locomotive, compared with one of 6 wheels, is as 5 to 8.

Ex.—An engine of 6 drivers weighs 30 tons—what are the maximum loads it can draw upon a level, and upon a grade of 250 feet, and what is its maximum grade for that load?

$$\frac{.2 \times 2240 \times 30}{.4242 + 8} = \frac{13440}{8.4242} = = 1595.4 \text{ tons on a level.}$$

$$\frac{.2 \times 2240 \times 30}{.4242 \times 250 + 8} = \frac{13440}{114.05} = = 117.8 \text{ tons up a grade of 250 feet.}$$

$$\frac{.2 \times 2240 \times 30 - 8 \times 117.8}{4242 \times 117.8} = \frac{12497}{49.47} = 250.1 \text{ feet.}$$

To Compute the Power, Speed, or Time of Running a Locomotive or Train upon a Railway.

On a Horizontal Plane.—H = the horse-power; S = space, in miles passed over in the time, t, in minutes; W = weight, in tons; constant of friction being 1-280 of the weight of the train.

$$\frac{1.28\,W \times S}{t} = H; \quad \frac{H\,t}{1.28\,W} = S; \quad \frac{1.28\,W \times S}{H} = t; \quad \frac{H\,t}{1.28\,S} = W.$$

What is the power required to draw a train of 50 tons, at speed of 45 miles per hour?

$$\frac{1.28 \times 50 \times 45}{60} = \frac{2880}{60}\ 48 \textit{ horses.}$$

In what time will a locomotive of 50 horse-power, drawing a train of 135 tons, run a distance of 80 miles?

$$\frac{1.28 \times 135 \times 80}{50} = \frac{13824}{50}\ 276.24 \text{ minutes.}$$

On an Inclined Plane.—h = rise or fall of the plane in every 100 feet.

$$\frac{256\,(5 \pm 14\,h)\,W \times S}{1000\,t} = H; \qquad \frac{1000\,t \times H}{.256\,(5 \pm 14\,h)\,W} = S;$$

$$\frac{256\,(6 \pm 14\,h)\,W \times S}{1000\,H} = t; \qquad \frac{1000\,t \times H}{256\,(5 \pm 14\,h)\,S} = W;$$

$$\frac{1000\,t \times H - 1280\,W \times S}{3584\,W \times S} = h.$$

Ex.—A train of 40 tons in weight ascends a road having a rise of 2 feet in 100, at a speed of 15 miles per hour—what is the power of the engine?

$$\frac{256 \times (5 + 14 \times 2) \times 40 \times 15}{1000 \times 60} = \frac{5068800}{6000} = 84.48 \text{ horses.}$$

N. B.—When a train or load descends a plane, h must be taken negatively, or $-$ as gravity in this case assists the moving power; when $h = 5\text{-}14$ of a foot, no moving power is required to draw the train.

Ex.—A train of 60 tons descends a road falling 3 inches in 100 feet, with a speed of 50 miles per hour—what is the horse-power exerted by the engine?

Here h is negative, and 3 inches $= .25$ feet.

$$\frac{256 \times (5 - 14.25) \times 50 \times 60}{1000 \times 60} = \frac{1152000}{6000} = 19.2 \text{ horses.}$$

Brakes.

The resistance of brakes is about 129 lbs. per ton of train. With a given amount of brake power, a train running at 40 miles an hour will run four times further before being stopped than it will at 20 miles an hour.

Mr. Fairbairn's experiments show that a train, moving at 20 miles per hour on a level, may be stopped by means of continuous brakes in a distance of 72 feet, and at 60 miles an hour in a distance of 636 feet.

A train, with locomotive, at 40 miles per hour, or 58⅔ feet per second, can be stopped on a level railway, if the friction of the wheels equals 1-7th of the weight, in a distance of 376 feet. A train thus moving at 58⅔ feet per second (40 miles per hour) has a stored-up energy, which, if directed upward in vacuo, would lift the train 43¾ feet high. If the adhesion of the wheels, suddenly arrested by the brakes, was equal to 1-5th of the weight, the train would be stopped in a distance of $53\frac{3}{4} \times 5 = 268\frac{3}{4}$ feet.

Formula for Actual Horse-Power of Locomotives.

$$H\ P = \frac{\text{Area of cyl. (sq. ins.)} \times \text{average press. (sq. ins.)} \times 2\ \text{stroke (ft.)} \times \text{number of revolutions (per min.)}}{33{,}000}$$

Table of Actual Horse-Power of Locomotives, of given Dimensions.

Boiler Pressure = 110 lbs. per square inch.

Diameter of each Cylinder.	Stroke of each Piston.	Diameter of Drivers.	Miles per Hour.	Cut Off and Mean Pressures.		
				¼ 44 Lbs.	½ 74 Lbs.	¾ 98 Lbs.
Inches.	Inches.	Inches.		H. P.	H. P.	H. P.
10	20	60	30	117	197	261
10	20	60	20	78	132	174
10	20	60	15	58	98	130
12	20	60	30	169	284	376
12	20	60	20	113	190	251
12	20	60	15	84	142	188
12	20	54	30	187	315	417
12	20	54	20	125	210	278
12	20	54	15	94	158	209
14	22	66	40	307	517	685
14	22	66	30	230	388	514
14	22	66	20	154	258	343
14	22	60	30	253	425	563
14	22	60	20	169	283	376
14	22	60	15	126	213	282
14	22	54	20	187	315	417
14	22	54	15	140	236	313
14	22	54	10	93	157	209
15	22	60	40	387	650	862
15	22	60	30	290	488	647
15	22	60	20	198	325	431

Table of H. P. of Locomotives, of Given Dimensions—Continued.

Diameter of each Cylinder.	Stroke of each Piston.	Diameter of Drivers.	Miles per Hour.	Cut Off and Mean Pressures.		
				¼ 44 Lbs.	½ 74 Lbs.	¾ 98 Lbs.
Inches.	Inches.	Inches.		H. P.	H. P.	H. P.
15	22	60	15	145	244	323
15	22	54	30	322	541	717
15	22	54	20	215	361	478
15	22	54	15	161	270	358
15	22	54	10	107	180	239
16	24	66	40	437	736	974
16	24	66	30	328	552	731
16	24	60	40	480	808	1,070
16	24	60	30	360	606	803
16	24	60	20	240	404	535
16	24	60	15	180	303	401
16	24	60	10	120	202	267
16	24	54	20	266	448	597
16	24	54	15	200	336	447
16	24	54	10	133	224	298
16	24	50	20	288	485	642
16	24	50	15	216	363	481
16	24	50	10	144	242	321
16	24	48	20	300	505	668
16	24	48	15	225	378	501
16	24	48	10	150	252	334
18	24	54	20	337	567	751
18	24	54	15	253	425	563
18	24	54	10	169	283	375
18	24	50	20	365	614	813
18	24	50	15	274	460	610
18	24	50	10	183	307	407
18	24	48	20	380	639	846
18	24	48	15	285	479	634
18	24	48	10	190	319	423

Table of Factors.

Table of factors, which multiplied by the total piston pressure, will give the tractive power of the locomotive in pounds.

Diameter of Driver.	Stroke in Inches.			
	18	20	22	24
4	2386	2652	2918	3182
4¼	2250	2500	2750	3000
4½	2151	2390	2593	2830
4¾	2012	2235	2459	2682
5	1910	2122	2334	2546
5½	1736	1929	2122	2315
6	1591	1768	1945	2122

The above are all decimals, and are got by dividing the double stroke by the wheel circumference, both in inches.

Speed of Trains.

Diameter of driving wheels in feet, multiplied by number of revolutions per minute, product multiplied by .0357, equal miles per hour.

Miles per hour divided by diameter of driving wheel in feet, quotient multiplied by 28, equal number of revolutions per minute.

60 divided by minutes, passing 1 mile = miles per hour.
3,600 " " seconds, " " " " " "
900 " " " " ¼ " " " "
60 multiplied by miles per minute, " " "
240 " " ¼ mile " " " "

Table of Piston Pressures.

For different Cylinders and different Steam Pressures.

Diameter of Cylinder.	Area of Piston.	Whole Pressure on both Pistons.			
		100 lbs.	110 lbs.	120 lbs.	130 lbs.
9	63.61	12722	13994	15266	16538
10	78.54	15708	17278	18849	20420
10½	86.59	17318	19049	20781	22513
11	95.03	19006	20906	22807	24707
11½	103.8	20760	22836	24912	26998
12	113.0	22600	24860	27120	29380
12½	122.7	24540	26994	29448	31902
13	132.7	26540	29194	31848	34502
13½	143.1	28620	31482	34344	37206
14	153.9	30780	33858	36936	40014
15	176.7	35340	38874	42408	45942
16	201.0	40200	44220	48240	52260
17	226.9	45380	49918	54456	58994
18	254.4	50880	55968	61056	66144
19	283.5	56700	62370	68040	73710
20	314.1	62800	69080	75360	81640

Effective Pressure of Steam on Piston.

With different Rates of Expansion; boiler pressure being assumed at 100 lbs. per square inch.

Steam cut off at ¾ of stroke = 90 effective pressure.
" " " ⅔ " = 80 " "
" " " ½ " = 69 " "
" " " ⅓ " = 50 " "
" " " ¼ " = 40 " "

Steam used in a Locomotive, for each Revolution of the Driving Wheel.

Steam used at one Revolution.

Cylinder.	Cubic ft. used.	Cylinder.	Cubic ft. used.
11 × 16	3.5197	15 × 22	8.9993
11 × 20	4.3996	15 × 24	9.8174
11½ × 16	3.8470	15½ × 22	9.6090
11¾ × 20	5.0200	16 × 18	8.3775
11¾ × 22	5.5220	16 × 20	9.3084
12 × 16	4.1890	16 × 22	10.2392
12 × 18	4.7123	16 × 24	11.1700
12 × 20	5.2360	16½ × 22	10.8890
12¼ × 16	4.3650	17 × 20	10.5083
12¾ × 16	4.7280	17 × 22	11.5591
13 × 20	6.1450	17 × 24	12.6099
13½ × 20	6.6268	18 × 20	11.7809
14 × 18	6.4140	18 × 22	12.9590
14 × 20	7.1270	18 × 24	14.1371
14¾ × 18	7.1200	19 × 22	14.4390
14¾ × 20	7.9110	20 × 22	15.9988
15 × 18	7.3631	16 × 26	12.1009
15 × 20	8.1812	15⅜ × 26	11.1740

Revolutions of Drivers per Mile.

Diam. in ins.	Rev. per mile.	Diam. in ins.	Rev. per mile.
42	480.4	62	325.4
43	469	63	320
46	439	66	306
48	420	72	280
50	403.5	78	258.6
54	373.5	81	249
55	367	84	240
60	336		

Table of Relative Travel, Lap and Lead,

For a Maximum Admission of 75 per cent. of the Stroke.

Travel, inches.	Lap, inches.	Lead, inches.	Travel, inches.	Lap, inches.	Lead, inches.
1 1-2	5-16 1-64	3-32	3 1-4	11-16 1-64	3-16 1-32
1 5-8	5-16 3-64	1-16 3-64	3 1-2	12-16 1-64	3-16 3-64
1 3-4	6-16	1-8	3 3-4	13-16	1-4
1 7-8	6-16 1-32	1-8	4	14-16	1-4 1-32
2	7-16	1-8 1-64	4 1-4	15-16	1-4 3-64
2 1-8	7-16 1-32	1-8 1-32	4 1-2	1	5-16
2 1-4	1-2	1-8 1-32	4 3-4	1 3-64	5-16 1-64
2 3-8	8-16 1-64	1-8 3-64	5	1 3-32	5-16 1-32
2 1-2	3-16 3-64	1-8 3-64	5 1-4	1 1-8 1-32	3-8
2 5-8	9-16 1-64	3-16	5 1-2	1 3-16 1-64	3-8
2 3-4	9-16 1-32	3-16	5 3-4	1 1-4	3-8 1-32
2 7-8	10-16	3-16 1-64	6	1 5-16	3-8 3-64
3	10-16 1-32	3-16 1-64	6 3-4	1 1-2	7-16 1-32

Tables Relating to Locomotives.

Rule for Lap and Lead of Locomotive Slide Valves.

Lap = travel × 0.22. | Lead = travel × 0.07.

Approximate Rules for the Proportion of Locomotives.

D = Diameter of Cylinder.

Area of steam ports..... $D^2 \times .08$
" exhaust port..... $D^2 \times .18$
Diameter of piston rod..... $D \times .15$
Thickness of piston..... $D \times .28$

Diameter of feed pump plunger, if of same stroke as the engine	$D \times .11$
Diameter of feed pipe	$D \times .12$
" " valve stem	$D \times .09$
" " driving axle	$D \times .4$
" " truck axle	$D \times .3$
Length of bearing driving axle	$D \times .43$
" " truck axle	$D \times .40$
Diameter of crank pin journal	$D \div .4$
" " shell of boiler	$D \times 3.11$
" " steam pipe	$D^2 \times .02$
" " exhaust nozzles	$D \times .3$
Area of section of connecting rods	$D \times .21$
Diameter of safety valve in inches	$D \div .4$
" " chimney	D
Area of fire grate in square feet	$D \times .77$
" " heating surface in square feet	$D^2 \times 5 \div 2$
Cubical contents steam room in cubic feet	$D^2 \times 9 \div 40$
" " of water room	$D^2 \times 9 \div 40$
Capacity of tenders in gallons	$D \times 112$
" " tanks of tank engines	$D \times 60$

Mercurial Gauge.

In common practice an atmosphere is taken as 15 lbs. per sq. in.

1 atmosphere, or 14.71 lbs. per square inch	= 29.22 inches of mercury.
Each pound pressure per square inch	= 2.04.
Each pound pressure per square inch	= 1.02 rise in a syphon gauge.
	= 1 inch approximately.
Each atmosphere, or 14.71 lbs. per square inch	= 33.9 feet of water.
Each pound pressure per square inch	= 27.7 inches of water nearly.

Dimensions of Locomotives,

From Actual Practice.

Description of Engine.	9-in. Outside Passer.	12-in. Outside Passer.	14-in. Outside Freight.	15-in. Outside Passer.	16-in. Outside Passer.	18-inch, 6 drivers, Freight.	18-inch, 6 drivers, Anthracite.	18-inch, 6 drivers, Br'd Gauge.
Diam. of Cylinder.....	9	12	14	15	16	18	18	18
L'gth of stroke.	15	20	22	22	24	24	24	24
Area of steam port.....	8	11	13	13	15.1	14	14	14
Area of eduction port....	16	22	23	26	30.37	31.5	31.5	31 5
Diam. of blast pipes.....	2¼	2¾	Variable.	3	3½	3½	4	3½
Diam. of pump ram.....	1½	1½	1¾	2	2	4½	4½	4½
Stroke of do...	15	20	22	22	24	5	5	5
Diam. of feed pipe.....	1½	1½	1¾	2	2	2	2	2
Length of connecting rod..	4.6	6.4	8.	8.1	7.0¼	7.6	7	7.6
Diam. of piston rod.....	1¼	1¾	2¼	2⅜	3	3	3	3
Depth of piston	3½	4¾	4¾	4¾	5	5	5	5
Diam. of crank pin.....	2x2½	3x2⅞	3½x3¼	3½x3¼	4½x4½	4½x4½	4½x4½	4½x4½
Diam. of back pin.....	....	2⅞x2⅞	3x3	3x3	3x3	3x3	3x3	3x3
Diam. of forward pin....	0	0	0	0	0	3x3	3x3	3x3
Diam. of crank axle.....	5½	5½	6	6	6½	6½	6½	6¼

DIMENSIONS OF LOCOMOTIVES—Continued.

Description of Engine.	9-in. Outside Passer.	12-in. Outside Passer.	14-in. Outside Freight.	15-in. Outside Passer.	16-in. Outside Passer.	18-inch, 6 drivers, Freight.	18-inch, 6 drivers, Anthracite.	18-inch, 6 drivers, Br'd Gauge.
Diam. of valve rod	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{3}{8}$
Length eccentric rods	4 0	4.3	$5.9\frac{5}{8}$	5.9	4.3	4.3	4.3	4.3
Diam. of eccentrics	$11'$	$11\frac{1}{2}$	$11\frac{1}{2}$	$11\frac{1}{2}$	14	14	14	14
Wid. of sheaves	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{5}{8}$	3	3	3	3
Diam. of boiler.	2.6	3 2	3.6	3.6	4.2	4.2	4 2	4.2
Length "	8.7	$15.8\frac{1}{2}$	$18.1\frac{3}{4}$	18.4	19.6	21.	23.8	20.4
No. of tubes	98	98	160	144	151	170	170	195
Superficial feet fire box	40	53.14	105 5	82	83.42	99.	90.2	108.
Do. tube surface	277	487.06	544	725	837	1068	1005	1123
Do. total heating surface	317	540	650	814	927.	1176	1102	1239
Ditto, fire grate surface	8	16.3	12.5	14	14.3	14.5	22.86	19.83
Ratio fire surface in sq. ft. to cubic contents of cyl'r.	..	206 to 1	166.6 to 1	181 to 1	166.2 to 1	166.5 to 1	156.2 to 1	175.5 to 1
Diam. of chimney	10	14	14	14	15	16	$14\frac{1}{2}$	16
Diameter truck axle	....	4	4	$4\frac{1}{4}$	$4\frac{1}{4}$	5	5	5

Weight of Locomotives and Tenders,

With Water and Fuel, in use on Railroads in United States.

Broad Gauge.

Cylinder.		Drivers.		Weights.		Tenders.	
Diameter inches.	Stroke inches.	Number.	Diameter feet.	Engine.	On Drivers.	Capacity gallons.	Weight.
9	16	2	4.6	32,154	18,399	530	Tank.
13	20	4	4.0	32,000	22,300	500	Tank.
15	20	4	6.0	54,700	33,920	1,617	40,100
16	24	4	5.0	71,300	44,000	2,000	40,000
17	24	4	5.0	67,000	40,050	2,000	42,240
17	22	6	4.0	71,050	54,000	2,000	40,000
18	22	4	5.6	73,332	45,817	2,200	41,000
18	24	6	4.6	87,444	72,156	2,200	41,000
19	22	8	3.7	56,000	56,000	1,976	37,400

Narrow Gauge.

12	20	4	5.0	36,000	22,000	1,200	26,600
13	22	4	5.0	43,200	27,000	1,400	28,200
14	22	4	5.6	51,000	32,000	1,600	31,566
15	22	4	5.0	54,000	33,500	1,800	33,166
16	22	4	5.6	58,000	36,000	2,000	34,766
16½	24	4	5.6	60,000	40,000	2,000	35,000
17	24	4	5.6	59,500	37,500	1,800	34,000
17	24	6	4.6	75,850	55,850	1,700	35,550
18	22	6	4.6	71,900	52,000	1,700	33,600
18	24	6	4.6	66,750	43,750	1,770	33,630
19	24	4	5.0	70,000	60,000	1,800	34,000
19	24	10	4.0	90,000	85,000	2,000	36,000

DIMENSIONS OF

Line on which the Engine Runs.	Northern of France.		
Kind of Engine.	Engerth. 4 Coupled Axles.	4 Coupled Axles.	4 Cylinders. 6 Driven Axles.
Diameter of cylinder, in inches	19.68	18.39	17.32
Length of stroke, in inches	25.98	18.89	17.32
Diameter of driving wheels, in inches	49.60	62.99	41.73
Pressure of steam, in pounds, per square in.	120	135	135
Heating surface of tubes, in square feet	2004.55	1687.76	2371.17
" " fire-box, in square feet	115.71	107.64	107.64
Total heating surface, in square feet	3120.26	1795.40*	2378.81†
Weight of engine, in tons, when at work	88	99	131.34
" tender, in tons, laden	50.16	....	....
Total w'ght, in tons, eng. & tend., when at work	138.16	99	131.34
Weight producing adhesion, in tons	88	99	131.34
Greatest load drawn, in tons	655	436	655
Speed regularly maintained in miles per hour, in ascending incline	12.4	12.4	12.4

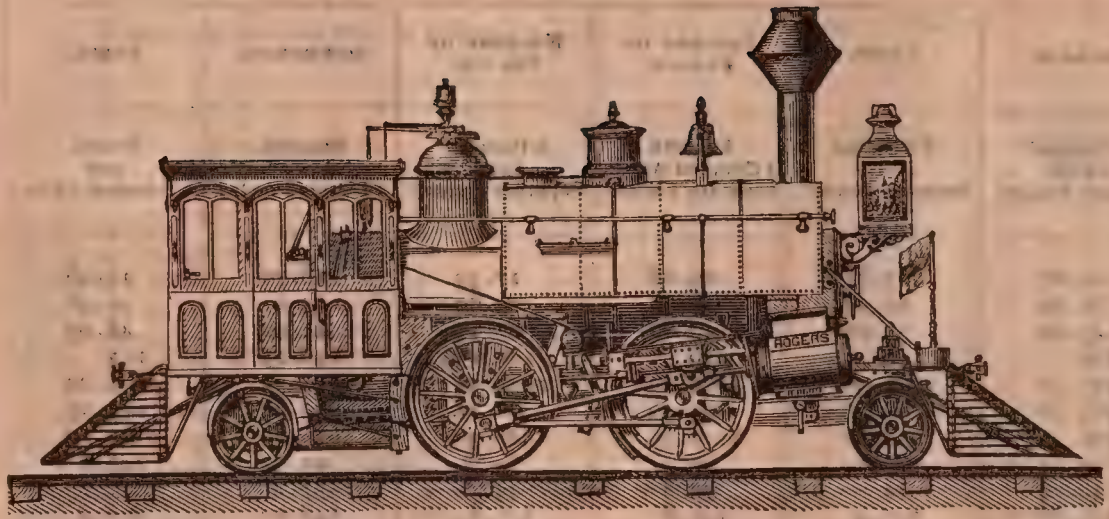
* To this add heating surface of super heater, 130 square feet.

FOREIGN LOCOMOTIVES.

Orleans.	Lyons.	Eastern of France.	Western of France.	Sœmmering.	Turin.
4 Coupled Axles, Separate Tender.	3 Coupled Axles, Separate Tender.	Engerth. 4 Coupled Axles, Separate Tender.	3 Coupled Axles, Separate Tender.	Engerth. Geared. 5 Coupled Axles.	Double and 6 Coupled Axles.
19.68	17.71	19.68	17.32	18.70	15.98
25.69	25.59	25.98	23.62	24.01	21.96
45.66	51.18	49.60	55.11	41.92	48.03
120	120	120	120.135	146.25	117
2111.08	1245.08	2022.09	1442.35	1571.51	2006.23
114.50	89.34	104.49	86.11	75.35	157.15
2226.36	1334.42	2126.58	1528.46	1646.86	2163.52
97.24	81.4	99	72.6	91.52	145.2
40.04	44	52.8	44	57.2	....
137.28	123.4	151.8	116.6	148.72	145.2
97.24	81.4	99	72.6	148.72	145.2
254	122	600	300	250	120
9.3	93	12.4	15.5	9.3	9.30

† To this add heating surface of super heater, 239 square feet.

Janney Wheel and Foundry Co.



W. S. HUDSON'S IMPROVED LOCOMOTIVE,

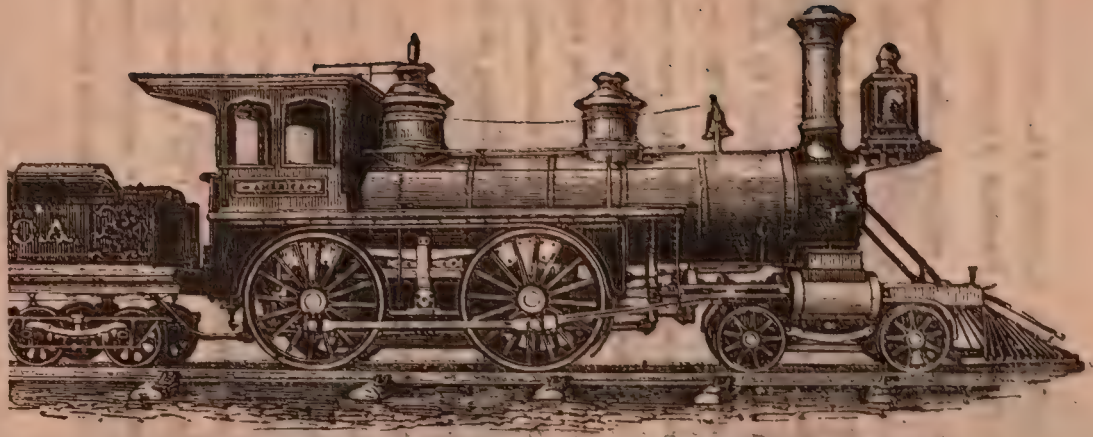
For Switching, Construction, and Branch Traffic.

ROGERS' LOCOMOTIVE AND MACHINE WORKS, PATERSON, N. J.

Wm. S. Hudson's Improved Locomotive, for Switching Construction, and Branch Traffic.

The improvement consists in supporting the weight of a tank locomotive on eight wheels, of which four are drivers and four truck, the truck wheels being arranged in two radiating trucks, one at each end of the locomotive. Each truck being connected with each pair of driving wheels by a combination of levers, the front truck and driving wheels are equivalent in action to a centre-bearing truck, and the rear truck and driving wheels to a side-bearing truck. By this arrangement all the wheels can accommodate themselves to the vertical inequalities of the track without changing the distribution of the weight, and without interfering with the radiating of the front and rear truck wheels of the engine.

The fixed wheel base of the engine may be made very short, so that the engine will pass readily around curves of very small radius, without the jumping motion incidental to the ordinary four-wheeled engine, and danger of leaving the track, and with diminished wear of the flanges of the driving wheels. From the perfect distribution of the weight, and its adaptation to the inequalities of the track, the motion of the engine is very easy, and correspondingly economical in the destruction of permanent way.



LOCOMOTIVE AMERICA,

BUILT AT THE GRANT LOCOMOTIVE WORKS,

Paterson, N. J.

PRIZE LOCOMOTIVE OF THE PARIS EXPOSITION, 1867.

Dimensions of Locomotive America,

Built at the Grant Locomotive Works, Paterson, N. J.

Diameter of cylinder, 16 ins.; stroke, 22 ins.; driving wheels, 5 ft. 7 ins.; truck wheels, 2 ft. 6 ins.; tender wheels, 2 ft. 6 ins.; total wheel base of engine, 22 ft. 3½ ins.; driving wheels, 8 ft. 6 ins. between centres; truck wheels, 5 ft. 9 ins. between centres; from trailing wheel to centre-pin of truck, 19 ft. 5 ins.; mean diameter of boiler, 48 ins.; copper tubes, 142, 2 ins. diameter, 10 ft. 11 ins. long; length of fire-grate, 5 ft. 6 ins.; width, 2 ft. 10 ins.; maximum depth of fire-box, 4 ft. 11½ ins.; tube surface, 812 sq. ft.; fire-box, 84 sq ft.; grate area, 15.62 sq. ft.; transverse distance apart of cylinders, 6 ft. 2 ins.; connecting rods, 7 ft. 3 ins. between centres; inside main steam pipe, 5⅝ ins.; branch pipes, oval section, 4½ × 3¾; steam ports, 16 ins. × 1¼ ins.; exhaust port, 16 ins. × 2½ ins.; outside lap of valve, ¾ in.; inside do., 3-32; lead in full gear, ⅛ in.; diameter of 2 blast nozzles, 3¾ ins.; diameter of driving axle, 6½ ins.; diameter of truck axle, 4½ ins.; diameter of driving axle journal, 6½ ins. × 7⅞ ins. long; truck axle journals, diameter 4½ × 8 ins. long; diameter of chimney, 15¾ ins.; height of do. above smoke-box, 5 ft. 7 ins.; above rail, 14 ft. 1½ ins.; centre of boiler above rail, 6 ft. 4 ins.; to top of cab from rail, 13 ft.; extreme width of cab, 9 ft. 1½ ins.

Weights.

Boiler, 9,500 lbs.; tubes, 2,344 lbs.; ash-pan, 490 lbs.; water-tube grates, 135 lbs.; fire-door, 80 lbs.; sand-box, 128 lbs.; bell, 228 lbs.; whistle, 28 lbs.; chimney saddle, 218 lbs.; smoke-box door, 174 lbs.; driving wheels, each 1,250 lbs.; counterweights, 270 lbs.; tyre, 2½-in., 835 lbs.; 1 cylinder, 2,210 lbs.

Weight of engine,	light	56,101 lbs.
" "	loaded	62,500 "
"	on drivers	38,500 "
"	on truck	24,000 "

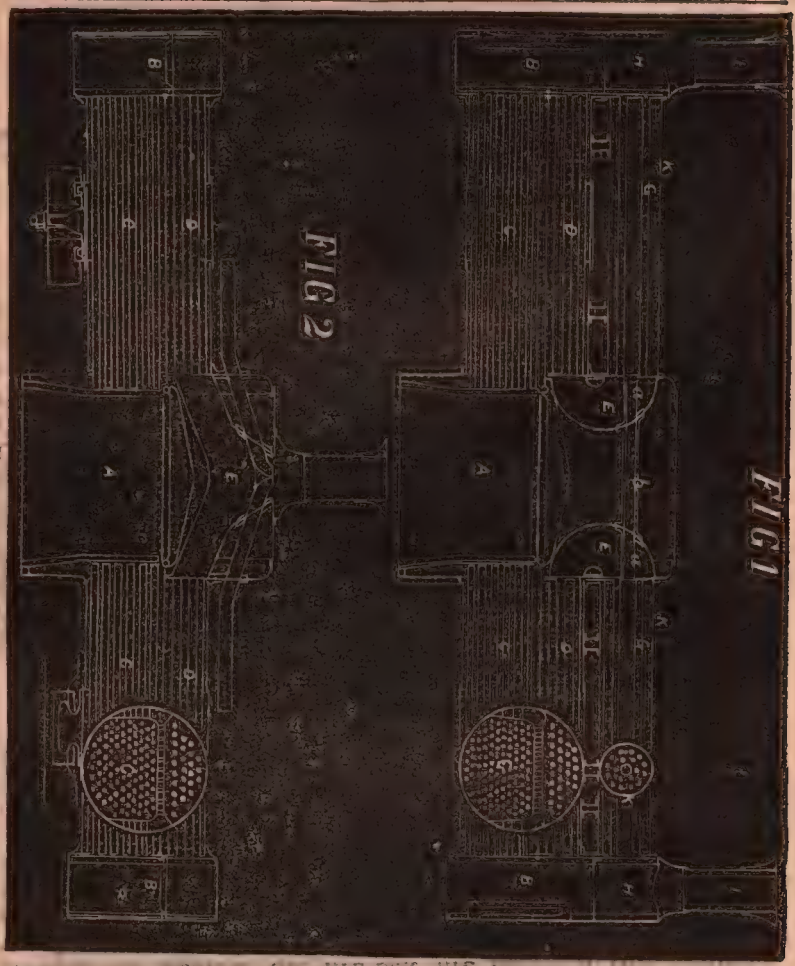
"FAIRLIE'S SYSTEM OF LOCOMOTIVE ENGINES."

Patented by R. F. Fairlie, Esq.

One of the worst features in the present construction of railways is, that while the weight on each car wheel is from 2 to 3½ tons, the whole line must be planed for a weight of from 5 to 7 tons per wheel, although this weight is carried on but 4 to 6 wheels, of 168 wheels of an ordinary train of 20 cars. When the weight on engine wheels is reduced to the standard weight on car wheels, lighter rails, chairs, sleepers, and less ballast can be used, with a decrease in the cost of their maintenance. This can only be done by the double-bogie system, whereby eight, ten, twelve, or more wheels can be worked with no more than 3 to 4 tons on a wheel, and without undue friction from coupling. An ordinary four-driver locomotive of 73,222 lbs., has an effective weight for traction on the drivers of 45,817 lbs., or 10,454 lbs. on each wheel; the tender, loaded, weighs 41,000 lbs., making the total dead weight uneffective for traction, to be hauled each time the engine moves 68,515 lbs., or the power requisite to move two passenger cars or four box cars, actually thrown away, to say nothing of the damage to the permanent way; or, in money: Suppose engine and tender to make 100 miles per day; dead weight hauled, 35 tons each mile; cost of hauling, 2 cents per ton per mile = 100 × 35 × 2 = $70; or, for 300 days, $21,000, which might be saved if the dead weight were made available for traction.

Mr. Fairlie proposes to utilize the unremunerative loss occasioned by the truck wheels—unremunerative, because, as far as tractive force is concerned, they are powerless—and the use of heavy tenders, and loss entailed by hauling their dead weight, and have an engine equally capable of running forward or backward, obviating the necessity of turn tables.

The accompanying diagrams illustrate Mr Fairlie's system. The system of locomotive is that of the 4-cylinder locomotive boiler, with a central fire-box, the barrel extending each way; at both ends are placed a pair of engines, which engines are fitted to bogie frames, the boiler resting on the frames by a centre pin, through which steam is admitted, the centre pin serving as a



FIGS. 1 AND 2.

A—Fire-box in centre.
B—Smoke or combustion chamber.
C—Tubes.
D—Upper series of tubes.
E—Upper smoke chamber.
F—Chimney (fig. 2).
G—Super heater flues (fig. 1).
H—Smoke-box over combustion chamber (fig. 1).
K—Super heating steam tube (fig. 1).
I—Chimney (fig. 1).

connection between the engine and the boiler, and around which the engine can swivel, allowing them to follow any curve or double reverse curve down to a radius of 1½ chains, without influencing the direction of one another; at the end of the engine-frames nearest the fire-box are fastened two segments, which, by means of quadrant links on the fire-box, transmit the drag of the engines, taking all the strain from the centre pin, the boiler serving as a main frame to connect the engines, which are free to radiate to suit the curvature of the track.

The engines are governed by the engineer, whose place is at one side of the fire-box, the fireman firing at the opposite side, the fuel and water being in tanks, placed on each side of the barrel of the boiler.

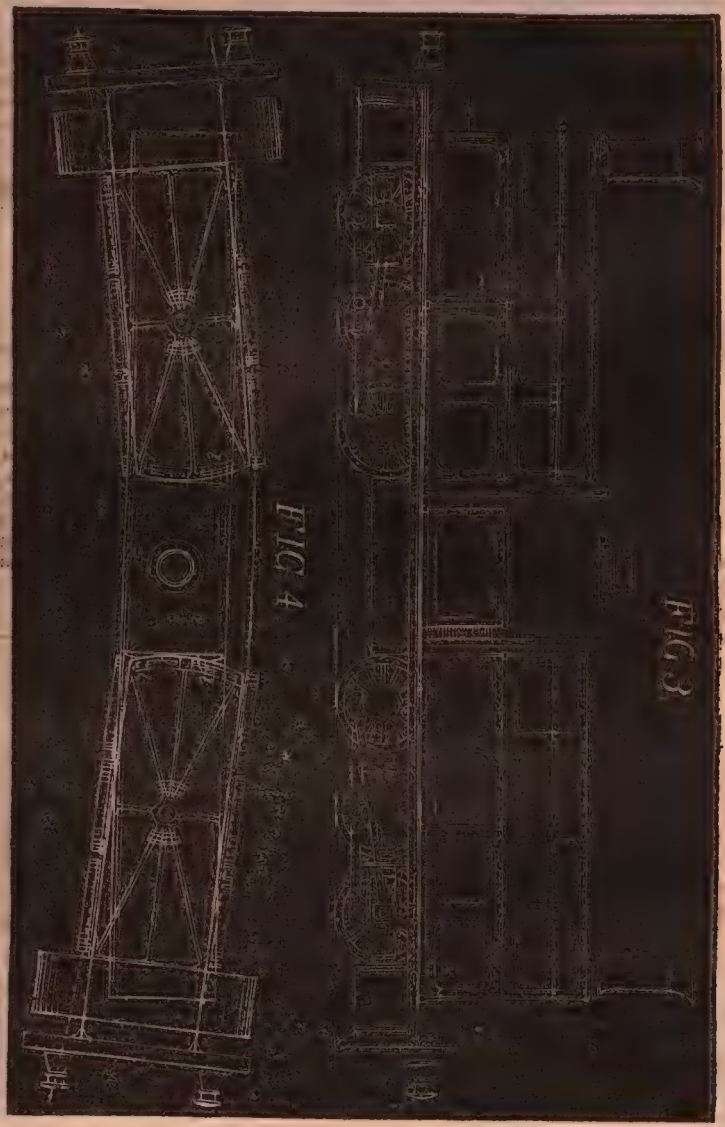
The Boiler.

Fig. 1 represents a boiler for a 12-wheeled engine; fig. 2, a boiler for an 8-wheeled engine; the fire-box, A, being in the centre; B, combustion chamber; C, tubes connecting fire-box; there being thus a set of tubes running in opposite directions from the fire-box; D is an upper series of tubes, from tube-plate in B to smoke chamber, E, placed inside of the fire-box shell over the fire-box, A; thus the heat and products of combustion from the fire-box, A, pass through the lower series of the tubes, C, in the usual manner, to the smoke-box, B, returning thence through the upper series of tubes, D, to the flue, E; thence, by the super heater, G, out of the chimney, F, on the 12-wheeled engines. On the 8-wheeled engines, fig. 2, the chimney is placed immediately over the centre of the smoke-box, E, in the middle of the boiler.

Description of Fairlie's Locomotives.

Figures 3 and 4.

Engine has 2 sets of 6 wheels, coupled, 3 feet 6 inches diameter.
Minimum radius of curve, 115.5 feet.
Distance between extreme centres of wheels of each frame, to determine radius of curve, 8 feet.
Weight of engine on the rails for "bite" or hold, 60 tons.
Weight on each wheel, 5 tons.
Number of cylinders, 4; diameter, 18 inches; stroke, 24 inches.
Tractive power of the engine at the rails, 35,550 lbs.



Ramapo Wheel and Foundry Co.

Capabilities of engine at velocities of 10 and 15 miles per hour on the level and up inclines as follows:

[NOTE.—*From the number of cars shown at each velocity, 6 should be taken as representing the weight of the engine.*]

Inclines.	Speed in miles per hour.	Load in tons.	No. of Cars, each 22,400 lbs.
Level.	10	4,347	434
1 in 100	10	1,204	120
1 in 40	10	582	56
1 in 20	10	311	31
1 in 12	10	170	17
Level.	15	4,006	400
1 in 100	15	1,166	116
1 in 40	15	574	57
1 in 20	15	308	30
1 in 12	15	166	15

Figures 5 and 6.

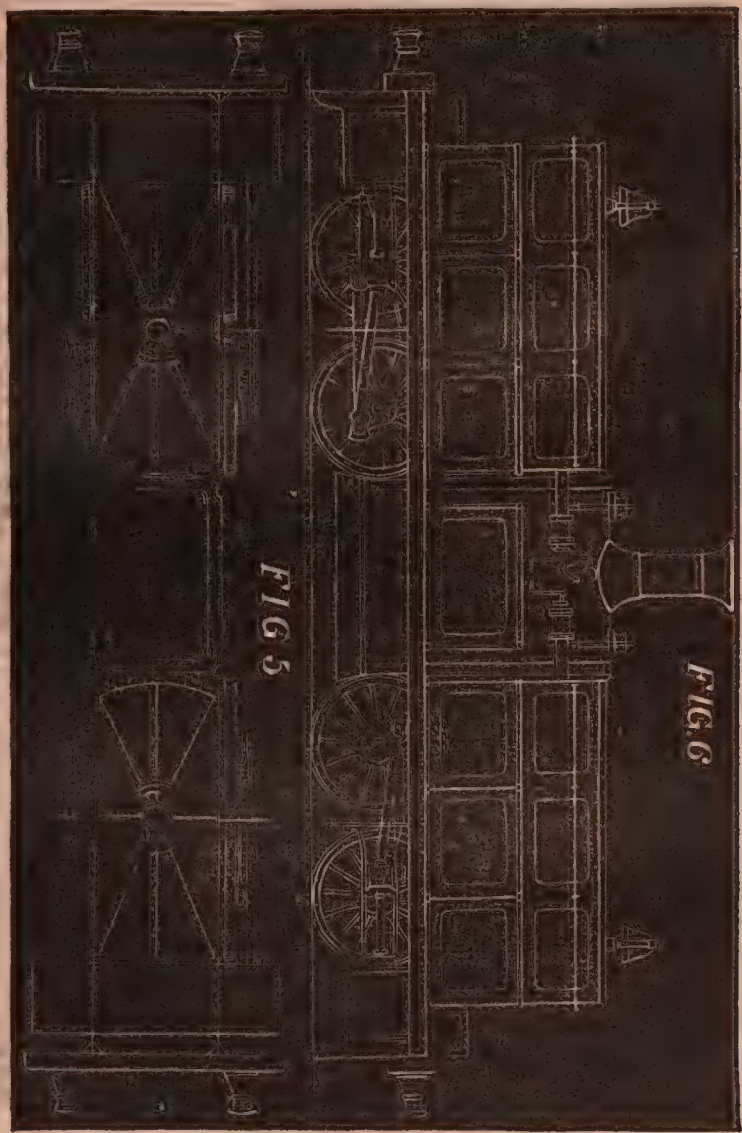
Passenger engine, 2 sets of 4 wheels, coupled, 6 feet 6 inches diameter.
Minimum radius of curve, 99 feet.
Distance between centres of wheels of each frame, to determine radius of curve, 7 feet.
Weight of engine on rails for "bite" or hold, 40 tons.
Weight on each wheel, 5 tons.
Number of cylinders, 4; diameter, 15 inches; stroke, 22 inches.
Tractive power of engine at rails, 12,185 lbs.
Capabilities of engine, at following velocities:

10 miles per hour;	weight in tons,	1,414;	No. of Cars,	at 22,400 lbs.	each,	141
20 "	"	"	"	1,179;	"	"	"	117
30 "	"	"	"	915;	"	"	"	91
40 "	"	"	"	699;	"	"	"	69
50 "	"	"	"	536;	"	"	"	53
60 "	"	"	"	419;	"	"	"	42

N. B.—From the number of cars shown at each velocity, deduct 4 for weight of engine.

Freight Engine, similar to Figures 5 and 6.

2 sets of 4 wheels, coupled, 4 feet 6 inches diameter.
Minimum radius of curve, 66 feet.
Distance between centres of wheels of each frame, to determine radius of curve, 5 feet.
Weight of engine on the rails, for "bite" or hold, 40 tons.



Ramapo Wheel and Foundry Co.

Weight on each wheel, 5 tons.
Number of cylinders, 4; diameter, 16 inches; stroke, 22 inches.
Tractive power of engine at rails, 20,024 lbs.
Capabilities of engine at velocities of 10 and 20 miles per hour on the level and up inclines, as follows:

Inclines.	Speed in miles per hour.	Load in tons.	No. of Cars, of 22,400 lbs. each.
Level.	10	2,332	233
1 in 100	10	646	64
1 in 40	10	312	31
1 in 20	10	169	17
1 in 12	10	104	10½
Level.	20	1,936	193
1 in 100	20	606	60
1 in 40	20	303	30
1 in 20	20	164	16.4
1 in 12	20	99	10

N. B.—From the number of cars, at each velocity, deduct 4, as the weight of the engine.

Engine for Light Passenger Traffic.

2 sets of 4 wheels, coupled, 4 feet diameter.
Minimum radius of curve, 49½ feet.
Distance between centres of wheels of each frame, to determine radius of curve, 4 feet 4 inches.
Weight of engine on the rails for "bite" or hold, 24 tons.
Weight on each wheel, 3 tons.
Number of cylinders, 4; diameter, 11 inches; stroke, 17 inches.
Tractive power of engine at the rails, 8,230 lbs.
Capabilities of engine at speeds of 20 and 30 miles per hour, and up inclines, as follows:

Inclines.	Speed per hour.	Tons.	Speed per hour.	Tons.
Level.	20	796	30	620
1 in 100	20	249	30	228
1 in 40	20	124	30	119
1 in 20	20	67	30	65
1 in 12	20	42	30	41

The weight in tons includes weight of the engine.

Performance of Locomotives.

Locomotive, by Messrs. M. W. Baird & Co., on Morris and Essex Railroad, 20-in. cylinder, 24-in. stroke; 3 coupled axles; drivers, 48 ins. diameter; heating surface in fire-box, 141 sq. ft.; heating surface in flues, 1,179 sq. ft.; total, 1,320 sq ft. Weight of engine on drivers, 78,512 lbs.; on truck, 9,408 lbs.; total, 87,920 lbs.; with a pressure of steam of 135 lbs., cutting off at 20 ins., hauled 557.12 tons, viz.: load = 369.8 tons; cars = 188.4 tons, net; up a grade of 77 feet to the mile, with a curve of 9 degrees.

A ten-wheeled locomotive, 18 × 22 cylinder, total weight 30 tons 9 cwt., weight on drivers 22 tons, on Reading Railroad, will haul 130 loaded cars; weight of coal, 675 tons; of cars, 380 tons; total load, 1,085 tons; on a down grade, maximum, 13.5 ft. per mile; minimum, 0.65 per mile. Same engine will haul 70 loaded cars, or 561 tons, over an ascending grade of 35.3 ft. per mile.

On the Pennsylvania Railroad, locomotives 18 × 22 cylinder, 3 coupled axles, wheels 48 ins. diameter, weight of engine 70,700 lbs., weight on drivers 65,800 lbs., will haul up a grade of 90 to 96 ft. per mile, for 12 miles, a train of 18 cars; weight of cars, 147 tons, net; total load on cars, 180 tons; total weight of train, 327 tons, net.

The standard 6-driver engine, cylinders 18 × 22 ins., of the Pennsylvania Railroad, total weight 73,100 lbs., weight on drivers 50,700 lbs., will haul 50 loaded 8-wheel cars; weight of cars, 410 tons; load 500 tons; total load, 901 tons, net; over a line generally level or descending, with occasional ascents at rate of 10 to 12 ft. per mile.

In the Sœmmering locomotive a power of 4.2 horses has been attained per ton of engine and tender; and 1 lb. of wood has raised 13,600 lbs. 1 foot in height per minute = 14.6 lbs. of wood per horse-power.

Freight locomotive on Northwestern Railway, England, has attained a power of 3.55 horses per ton of engine and tender.

1,192 square feet of heating surface, and 74 square feet of grate surface, in a locomotive boiler, gave identical results with a plane cylindrical boiler of 118,409 feet heating surface, and 96 feet of grate surface.

Ramapo Wheel and Foundry Co.

Freight Engine "Vulcan"—Rogers L. & M. Works, makers. 6 drivers; 51 ins. diameter; cylinders 16 × 24 ins.; made 617 trips, or 55,530 miles in 2 years and 15 days hauled 18,295 eight-wheeled cars; average number of cars to a train, 30; actual gross weight hauled per train, 440 tons, at a total cost for repairs of $1,140 (gold), or 2½ cents per mile run.

Coal Locomotives Nos. 34 and 35—N. Y. and New Haven R. R. Cylinders 17 × 22 ins.; 4 drivers; 5 ft. 9 ins. diameter; will haul trains of passenger cars, averaging 8½ cars, with one ton of coal, for 54 1-5 miles, at a cost of 11.29 cents (currency) per mile; oil and waste, 1.64 cents per mile.

New York City Street Dummy Engines. Cylinders 6 ins. × 10 ins. stroke; can haul 2 cars, containing 100 passengers each, up a grade of 100 ft. per mile, at 5 miles per hour; on a level and low grades, at 10 miles per hour; runs 125 miles per day; burns 1,200 pounds of coal; pressure of steam, 130 pounds; in shop for repairs one-sixth of the year.

French Locomotives.—Average actual power exerted, 450 horses; average speed of passenger trains with 15 vehicles is 24 miles per hour; freight trains, 18 miles; mixed engines, 20 to 30 miles per hour.

A Crampton Locomotive drawing 12 carriages, consumes 35 lbs. of coke per mile in summer time, 37 lbs. in winter. The cost of running a trip per mile, every item included, is 33 cts. (gold). An engine is generally worn out when it has travelled 186,000 miles; usually performs 15,500 miles per annum; its lifetime may be taken at 10 years; the cost of engine, $9,600 (gold); tender, $2,200. Crampton engines, with fuel and water, weigh 99,000 lbs.; without tender, 59,400 lbs.; mixed engines, 77,000 lbs.; without tender, 44,000 lbs.; Engerth engines, 138,600 lbs.; without tender, 88,000 lbs. A first class carriage weighs 12,320 lbs.; costs $2,000 (gold); if with coupé, $2,200; a second class carriage weighs 13,640 lbs.; costs $1,200; a third class weighs 14,520 lbs.; costs $1,000. The old Diligence weighed 8,800 lbs.

Dummy Locomotive for City Service.

(A. F. Smith's Patent.)

The dummy engines built on this patent consist of a pair of locomotive cylinders—11 ins. diameter, 15 ins. stroke—placed horizontal, side by side, at the centre of frame of a car made of iron, with an upright tubular boiler, the exhaust steam passing through a surface condenser, which receives its condensing water from tanks, which form the sides of the car, the circulation being produced by the difference of temperature between the water in the tanks and in the condenser, condensation taking place until the circulation ceases by reason of the water in the tank becoming too hot to condense the steam; the circulation is also aided by the feed pumps, which take their supply from a hot well connected with the condenser.

Being entirely free from smoke, noise or escape of steam, urning short curves, and easily handled, they can be used without annoyance in crowded thoroughfares, and are much more economical than horses.

Dimensions.—Cylinders, 12 ins. diameter, 15 ins. stroke, transmitting power to engine shaft, which is geared 2½ to 1 on an auxiliary shaft at centre of car, from the cranks on end of which connecting rods transmit motion to a driving axle in front and rear, equidistant from the centre; 4 driving wheels, 42 ins. diameter, steel tyres; wheel base, 9 ft. 11 ins

Boiler, upright tubular, 45 ins. diameter, 9 ft. 6 ins. high; fire grate, 36 ins. diameter; furnace, 4 ft. 6 ins. high; 325 vertical tubes, 1¼ ins. diameter, 60 ins. long; pressure of steam, 110 lbs.; condenser, 40 ins. long × 36 ins. wide × 20 ins. deep, with 704 vertical tubes, ¾ ins. diameter × 14½ ins. long; 2 water tanks, 5 ft. deep × 7 ins. wide × 21 ft. long, with circulating pipes at one end connecting tanks, at the other with condenser; feed pumps, 3 ins. diameter × 4½ ins. stroke; total length of engine, 27 ft.; 25 ft. 8 ins. over body; 9 ft. 4 ins. wide; usual speed, 6 miles per hour; usual load, 18 cars, loaded; total weight, with fuel and water, 21 tons; fuel, anthracite coal. Average cost per car, hauled one mile: fuel and stores, $0 3.52; repairs, $0 2.35; wages, $0 4.92; total cost per car per mile, $0 10.79. Pounds of coal per car per mile = 10.59; pints of oil, 0.0556. Economy as compared with horses, as 1 to 6.

Ramapo Wheel and Foundry Co.

Rolling Stock.

Number of Engines, Carriages, etc., for each 100 Miles of Railway.

	England.	Scotland.	Ireland.
Passenger engines	24	23	13
Goods "	32	28	8
Tank "	8	4	6
Total number of engines	64	55	27
First-class carriages	37	34	22
Second "	48	32	17
Third "	43	55	25
Composite and other carriages	20	11	12
Total number of carriages	148	132	76
Horse boxes	20	13	9
Carriage trucks	17	11	9
Goods wagons	715	700	223
Mineral and other wagons	1,094	980	49
Cattle wagons	95	81	58
Total wagons	1,904	1,761	330

Working Expenses.

On the railways of Great Britain the proportion of the details of working expenses are as follows:

Maintenance of way	= 15	per cent.
Locomotive and carriage department	= 38	"
Traffic charges	= 26	"
Miscellaneous, including police, watching, compensation	= 14	"
Duty, rates, etc	= 7	"
Total expenses	100	"

Richmond Iron.

Average Weight of Cars—4 feet 8½ inches Gauge.

As in use on Principal Railways in the United States.

Baggage car, 36 feet out to out, weight	28,000 lbs.
Mail car	32,000 "
Passenger car, 48 feet out to out, weight	37,000 to 39,000 lbs.
Sleeping car	41,000 to 44,000 "
Stock car	17,500 to 18,500 "
Box car	16,400 to 17,800 "
Flat car, 32 feet long	15,500 lbs.
8-wheeled coal cars	13,440 "
4-wheeled coal cars	6,720 "
Iron trucks for passenger cars	16,000 "
Wooden trucks for passenger cars	14,000 "
Passenger car, axles of iron	310 "
Passenger car, axles of steel	320 "
Freight car, axles of iron	305 "

Dimensions, Capacity, and Weight of Cars—4 feet 8½ inches Gauge.

Class.	Length Over Body.	Length Over All.	Breadth Over Body.	Breadth Over All.	No. of Wheels.	Weight in Lbs.	Capacity.
	Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft. Ins.			
1st Class Pass.	45. 0	52. 6	10. 0	10. 6	8	30,000	56 Pass.
Sleeper	53. 0	61. 6	10. 9	11. 6	12	38,000	48 "
2d Class Pass.	45. 0	52. 6	10. 0	10. 6	8	30,000	54 "
Emigrant Pass.	34. 0	41. 0	10. 0	10. 7	8	21,000	60 "
" "	29. 0	36. 0	9. 2	9. 9	8	20,000	52 "
P. O. and Bag.	50. 0	57. 0	10. 0	10. 9	12	27,000	15 tons.
" "	44. 0	51. 0	10. 0	10. 9	8	25,000	12 "
" "	36. 0	43. 0	10. 0	10. 9	8	20,000	12 "
" "	29. 0	36. 0	9. 0	9. 9	8	19,000	10 "
Conductors	29. 0	32. 0	9. 0	10. 0	8	20,000	10 "
Box Freight	29. 0	32. 0	9. 0	10. 0	8	18,000	10 "
Grain	20. 0	22. 6	9. 0	10. 0	4	12,000	7 "
Cattle	29. 0	32. 0	9. 0	10. 0	8	18,000	10 "
" 2 decks	29. 0	32. 0	9. 0	10. 0	8	19,500	10 "
Timber Cars	61. 0	65. 0	9. 6	10. 6	16	38,000	40 "
" Trucks.	11. 0	14. 0	7. 5	10. 0	4	8,000	5 "
Platform	29. 0	32. 0	9. 0	10 0	8	16,500	10 "
Engine Platf'rm	45. 0	48. 0	10. 3	10. 0	12	34,000	40 "
Dump	12. 3	16. 3	7. 8	8. 0	4	10,000	7 "

Passenger Cars—4 feet 8½ inches Gauge.

For 60 persons: Body 48 ft.; length over platform, 54 ft.; width, 9 ft. 6 ins.; height at sides, 7 ft. 10 ins.; at dome, 10 ft. 3 ins.; saloon, 6 ft. × 2 ft. 9 ins.; passage between seats, 1 ft. 10 ins.; seats 1 ft. 4 ins. wide, 3 ft. 2 ins. long inside, 1 ft. 4 ins. from floor; sash lights, 2 ft. × 2 ft. 7 ins.; doors, 2 ft. 3 in. × 6 ft. 4 ins.; framing—2 side sills, 5½ × 9; 4 inside do., 4 × 9; end do., 6 × 9; transom beams, 9 × 14; pillars, 2 × 3; end do., 5 ins. rad.; flooring, 1⅛ ins., double, laid diagonal, crossed at angle of 45°; 2 truss rods, 1⅛ ins., iron; dome braced by iron knees, 2 × ⅜ ins.; platforms, 2 ft. 6 ins. wide; bumper beam, 7 × 8 at centre, 4 × 3½ at ends; weight, empty, 39,000 lbs.; dead weight per passenger, 650 lbs.; weight, loaded, 46,980 lbs.; load on each wheel, light, 3,250 lbs.; if loaded, 3,915 lbs.

Sleeping Coach.

For 64 passengers: Body 61 ft. long, 8 ft. 10 ins. wide inside, 7 ft. 10 ins. high at sides, 9 ft. 7 ins. at dome; carried on twelve 33-in. wheels, 16 elliptic springs, 36-in. centres, 5 leaves, 5-16 ins., 1 do., ⅜ × 3½, steel—weight, 93¾ lbs. each—and 8 rubber springs over axles, 8 × 7; dead weight, without passengers, 26 tons, or 812.5 lbs. per passenger; if loaded, 945.5 lbs. per passenger; load on each wheel = 5,042 lbs. Western Palace cars, on 16 wheels, loaded, weigh 78,500 lbs., or 4,907 lbs. load on each wheel.

Box Cars.

27 ft. 5 ins. long, 8 ft. 6 ins. wide, 7 ft. 3 ins. high at sides, 8 ft. at roof; doors, 5 ft. × 5 ft. 10 ins.; track to top of car, 10 ft. 10 ins.; timbers—2 side sills, 4¼ × 8; 4 inside do., 3½ × 8; end do., 5 × 8½; transoms, 5 × 12; pillars for doors, 3½ × 4; end do., 3½ × 4¼; plates, 5 × 3½; ridge beam, 2½ × 3½; rafters—1¾ × 3½ at sides, 1¾ × 12 at centre, intermediates 1¾ × 2½; weight, 17,800 lbs.; do., loaded, 37,800 lbs.; dead weight for each ton carried, if loaded, 1,780 lbs; load on each wheel, if light, 2,225 lbs.; if loaded to capacity, 4,725 lbs.

Baggage Cars.

45 ft. long, 9 ft. 4 ins. wide, 7 ft. 4 ins. at sides, 9 ft. at crown of roof; end doors, 2 ft. 2 ins. × 6 ft. 4 in.; end side doors, 3 ft. × 6 ft. 2 ins.; centre doors, 3 ft. 10 ins. × 6 ft. 2 ins.; timbers—6 longitudinal sills, 5½ × 9½; 4 truss rods, 1⅛ ins., iron; weight of car, 27,000 lbs.; capacity, 12 tons; total weight, if loaded, 51,000 lbs.; carried on 8 wheels = 6,375 lbs. on each wheel.

Coal Cars—8 Wheels.

10-ton, 8-wheel cars: Body, 20 ft. long, 21 ft. 10 in. over all; 7 ft. wide, 7 ft. 8 in. over all × 4 ft. high; from top of rail to body, 2 ft. 6½ ins.; rail to centre of buffer, 2 ft. 7½ ins.; buffers, 10 × 12 ins.; 2 ft. 1 in. centre to centre; total weight, empty, 13,440 lbs.; loaded, 35,840 lbs.; per wheel = 4,480 lbs.

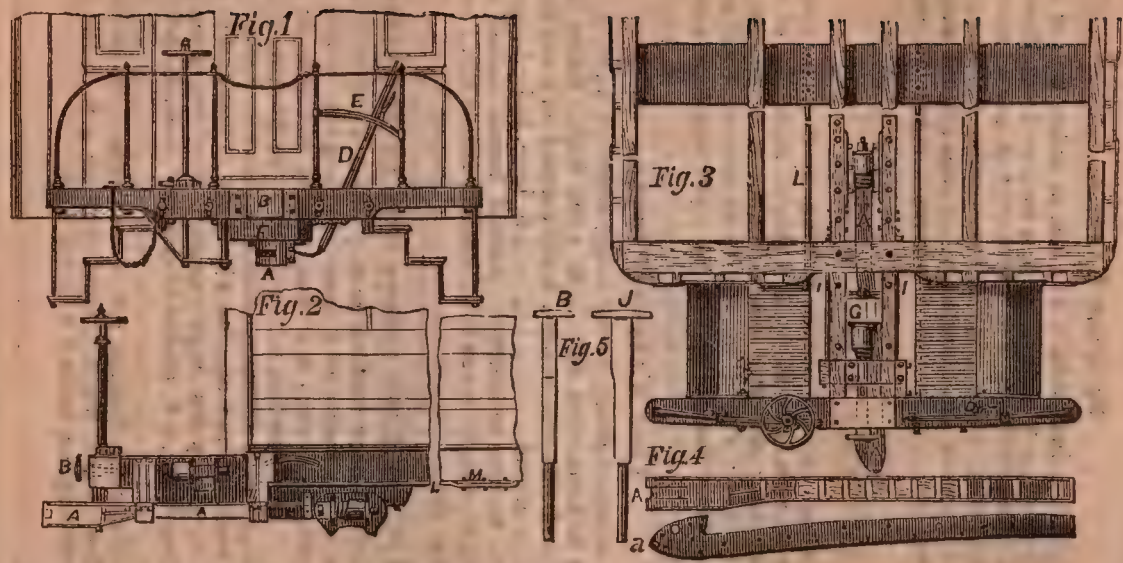
Coal Cars—4 Wheels.

6 tons, 4 wheels: Body, 11 ft. long; over all, 13 ft. × 6 ft. 7 ins. wide; 7 ft. 5 ins. over all × 4 ft. 3 ins. high; frame of oak, 4¼ × 8½; end sills, 8½ × 9½; body carried on 4 oak springs, each 3 × 6¾; at ends, 2½ × 6¾ × 9 ft. long, bolted together; wheels, 5 ft. centre to centre; journal boxes bolted to the springs; weight, empty, 6,720 lbs., loaded, 20,160 lbs.; on each wheel = 5,040 lbs.

English Railway Carriages—4 feet 8½ inches Gauge.

Extreme length over buffers, 22 ft.; frame, 17 ft. 11 ins. long × 6 ft. 8 ins. wide; body, 18 ft. long × 7 ft. 4 ins. × 6 ft. 2 ins. high; compartments, each 6 ft. long; sides and ends of under framing, 11 × 4; transoms, 9 × 3 × 11 × 3; framing of body, 3 × 2½ × 2½ × 2½; flooring, 2 thicknesses of ¾ boarding, laid diagonally; roof, ¾ thick on ribs, 2½ × 1¾, 2 feet apart; doors, 1 ft. 11 ins. × 5 ft. 5 ins. high; seats, 1 ft. 6 ins. from floor; wheels, 36 ins. diam., 9 ft. centre to centre; journals, 6 ft. 4 ins. apart.

Freight Wagons.—Bodies, 7 ft. 6 ins. wide × 16 ft. long, 20 ft. over buffers; open wagons, sides 2 ft. to 4 ft. 6 ins. high; covered goods wagons, sides 6 ft. 9 ins. high.



MILLER'S PATENT PLATFORM, COUPLERS, AND BUFFERS.

MILLER'S PATENT PLATFORM, COUPLERS, AND BUFFERS,

For Railroad Cars.

Until the adoption of Mr. Miller's improvement for cars, no portion of the American railway practice required remodeling more than the plan generally in use for COUPLING CARS together. In the items of repairs, broken drawheads and end-sills have been among the largest.

In Europe and England, screw couplings for attaching cars have long been in use, and surprise shown that we were so slow to remedy our faulty method.

The master car builders of the United States, in convention at Springfield, Mass., May 15, 1867, feeling the necessity for an improvement, unanimously adopted the following resolution:

"*That the common method of allowing the point of contact, at which compression is received on our passenger trains, to be some distance below the line of effective resistance to such force, is wrong in principle. And we respectfully recommend to our respective companies the propriety of adopting such a method of construction in the details for coupling the cars of passenger trains together as shall obviate such difficulty.*"

The plan of coupling will be understood from the following description and cuts.

DESCRIPTION.

Figure 1 is an elevation; Figure 2, a longitudinal section; Figure 3, a plan of an end of a car to which the arrangement has been applied; and Figures 4 and 5 show top and side views of the "Hook" and "Buffer," drawn on a larger scale than that of Figures 1, 2, and 3.

The letters refer to the same parts in all the figures. A is the coupling "Hook;" B the "Buffer;" C the "Stop;" D the "Lever;" E the "Quadrant Ratchet;" F the "Truss Beam;" G the "Spring Beam;" H the "Suspender Beam;" I the "Upward Trusses;" K the "Main Spring;" L the "Downward Trusses;" and M the "Bolster."

The platforms, instead of being located below the centre line of the main sills of the car, are placed *in* that line, and held there by the Trusses I and L, so that the point of contact (in Buffers B is *in* the said centre line and *not below it*.

The coupling "Hook" A is attached to the draw spring the same as the ordinary drawhead, and at the same height above the track, but in such a manner that the outer end is free to move laterally for a short distance. The Coupling Hook projects beyond the platform. The Stop C is placed

under the Buffer Beam to prevent accidental uncoupling. When two cars are brought together, the Coupling Hooks, from *their shape*, push each other aside, until the Buffers B are compressed hard on the Buffer Springs, the i—*the points of the Hooks having passed each other sufficiently far*—the Hooks are carried forward by their main-springs, and thus the "*Coupling*" and "*Compression*" are both effected automatically *and at the same time*, and without the use of links and pins. When two cars are thus coupled together, the *head* of the *Hook* of each car is under the Buffer Beam of its opposite car, and the platforms are close together (about 4 inches apart). The effect of this is, *one platform cannot be forced over the other*, nor can a *child* fall between the platforms; the dust and rain are nearly all shut out; the "Compression" makes the trains run steadily, and prevents all jerking at starting and stopping.

THE ADVANTAGES ARE:

1. The platforms are held in a plane with the sills of the cars.
2. The platforms cannot be broken by any ordinary accident.
3. Telescoping is entirely prevented.
4. Any required compression may be attained.
5. No links and pins are required.
6. The platforms may be held as close together as desired.
7. By close coupling the train is shortened.
8. They will not accidentally uncouple.
9. They may be uncoupled "*without shutting off*," to make a *flying switch*.
10. They very much reduce lateral and vertical *vibration* of the cars.
11. They cause the train to run steady and not jerk in starting and stopping.
12. They work well at great variations of height.
13. They will couple with all kinds of "drawheads" and "couplers."
14. They are cheap and durable.
15. Injury to men when coupling cars is entirely prevented.
16. Injury to persons by falling between cars is entirely prevented.
17. Injury to persons and to cars by "telescoping" is entirely prevented.
18. Damage by broken platforms is prevented.
19. Cars coupled in this manner are *not so liable to run off broken rails*.
20. "*Train Brakes*" are rendered more valuable by the non-existence of "*slack*" in the train.

The following cuts—Figures 1, 2, and 3—show a comparison of the effects caused by collision between cars when equipped with a Miller Coupling, or with ordinary shackle and pin.

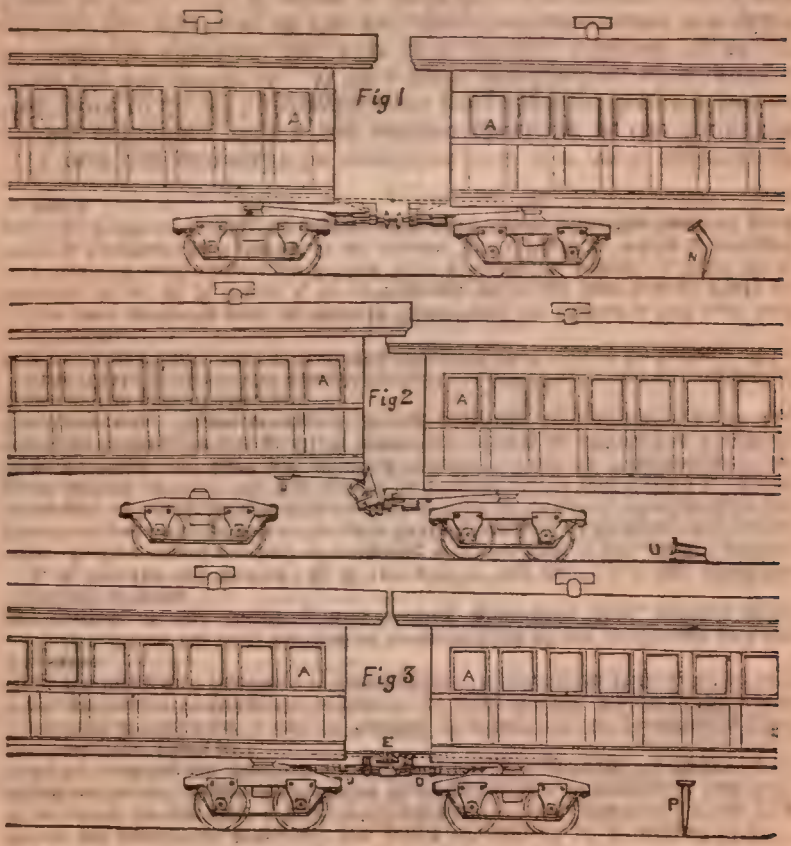


Plate 1 shows the mechanical errors in the construction and location of passenger-car platforms, and in the arrangement of the coupling and buffing apparatus.

A, A, are the car bodies; B, B, the sills of the cars; c, c, the platform

sills; D, D, the drawheads—which serve also as buffers. E, the coupling link; f f'' f the centre line of the sills of the cars; g, the point of contact; and h, g, the line of depression from the centre line f f'' f to the point of contact at g.

These platforms are located *below* the sills of the cars, and the buffers far below the platforms, bringing the point of contact at g instead of at f'' This crook in the line f, h, g, will INSURE a broken platform, even in a slight collision. Some car-builders have attempted to surmount this difficulty by making the platforms narrower, but this *increases the danger*, as it increases the angle at h.

Plate 2 shows how a car, in motion, is raised up, by breaking a platform, and made to strike the opposite car *above its sills*, where nothing but light studding and paneling is encountered in its course into and through the same.

Plate 3 shows the only method of construction of car platforms and the application of the coupling and bufling apparatus that accords with mechanical laws.

A, A, are the car bodies; B, B, the sills of the cars; c, c, the platform sills; D, D, a novel method of coupling without link or pin, or any substitute therefor, and entirely automatic in its operation. This kind of coupling is capable of being attached to any other kind of coupler, whether it is the same height or not. E, the buffer, is located *in the centre line* f f. These buffers—when the cars are coupled together—may be "compressed" as much as desired, or not at all, if preferred; and g, g, shows the course of the truss rods. These trusses hold the platform in its line—*i. e.*, in the plane of the sills of the cars.

This (Plate 3) shows the *straight line* method of bufling; and any mechanic can see, at a glance, that it insures a platform that cannot be broken off by a collision.

The two methods may be plainly illustrated by taking a cut nail and bending it, as at N, Plate 1, to correspond with the line f, h, g, Plate 1; this crooked nail cannot be driven into a soft pine board; a light blow with a hammer will break it, as shown at O, Plate 2; while a straight nail—as P, Plate 3—may be driven with hard blows into the hardest kind of wood.

It may not generally be conceded, but it is well understood among engineers, that a too sudden checking of the train has had more to do with throwing cars from the line than the public generally are aware of. With a loose shackle-bar, when a train is suddenly checked, the rear cars generally crowd up to or overlap the platform of the car ahead, which causes the platforms to break off; if going at from fifteen to twenty miles per hour and suddenly checked, the cars frequently mount upon each other, and pass into, if not through, and TELESCOPE into each other, causing great loss of life. With broken rails, cars

with these equipments are less liable to leave the track. *Compressing the buffers* and *restricting the lateral liberty of the cars*, compel them to *follow the locomotive*, which seldom goes off the track at a broken rail, and prevents TELESCOPING—a not unfrequent result from running off from broken rails, which is the cause of at least twenty-five per cent. of all accidents. The Erie, Hudson River, New York and Harlem, Michigan Southern and Northern Indiana, Chicago, Burlington and Quincy, etc., have adopted, after thorough trial, this improvement, and before long it will be in use on all passenger equipment of the couutry.

Communications may be addressed to E. MILLER, Post-Office box 2,996, or Rooms 4 and 5, No. 231 Broadway, New York City, N. Y.

VENTILATION IN CARS.

The cubic contents of an ordinary car, seating 50 persons, is about 5,000 feet.

An adult inspires and expires, on an average, 30 cubic inches at each respiration; breathes 16 times a minute, or 480 cubic inches per minute, or 28,800 cubic inches or 16.66 cubic feet expired per hour. The air he breathes, if pure, contains 0.4 per 1,000 volumes of carbonic acid, while that he gives out contains 40 volumes per 1,000 of carbonic acid, which is in addition to the organic matter and watery vapor, or from 12 to 16 cubic feet in 24 hours. To dilute the expired air so that the amount of carbonic acid shall be reduced to 0.4 per 1,000, more than 100 times the volume of such air must be supplied per hour (or 16.60 cubic feet), to which must be added ¼ more for the exhalations from the skin, and the carbonic acid in the fresh air which has been added, which augments the amount to 2,082 cubic feet per hour per each adult.

By the skin and lungs, 25 to 40 ounces of water pass off in 24 hours, to maintain which in a state of vapor requires 211 cubic feet of air per hour. Air vitiated by respiration smells of organic matter when the carbonic acid reaches 0.7 per 1,000 volumes, and is very much vitiated when the carbonic acid reaches 1 in 1,000. Air to be kept pure must be continually changing to the amount of at least 2,000 cubic feet per hour for each well persou, and double that amount for a sick person; or, in a car seating 50 persons, at least 100,000 cubic feet of fresh air must be added each hour.

Kampo Wheel and Foundry Co.

RAILWAYS.

Regulations for Construction of Prussian Railways and Rolling Stock.

Railway 4 feet 8½ inch Gauge.

Minimum breadth of roadway, double line	24 ft. 9 in.
" " single line	15 ft. 6 in.
Maximum gradient, level districts	1 in 200
" hilly districts	1 in 100
" mountainous districts	1 in 40
Minimum radius of curves, flat districts	3,600 feet.
" " hilly districts	1,200 feet.
" " mountainous districts	600 feet.
Maximum gauge for straight lines and curves of more than 1,000 feet radius	4 ft. 8½ in.
Maximum gauge round sharp curves	4 ft. 9½ in.
Minimum width of top table of rails	2¼ inches.
Radius of " " from	7 to 5 in.
Minimum depth of rails	4½ inches.
Inclination of rails inwards	1 in 20
Minimum depth of ballast under sleepers	8 inches.

Level Crossings and Stations.

Minimum angle of crossing with rails	30°
" width of channel for flange at crossings	2⅝ inches.
" depth of " "	1½ inch.
" portion of level at stations, flat districts	1,800 feet.
" " " mountainous do	600 feet.
" distance, centre to centre of rail in station	14 feet.
" radius of crossings and turnouts	600 feet.
" " for facing points at stations for through trains	1,000 feet.
" diameter of engine turn-tables	38 feet.
" width of passenger platforms	18 feet.
Maximum height	18 inches.
Minimum distance of pillars in stations from rails	9 ft. 5 in.
" diameter of water-crane pipes	6 inches.
" height of fixed portion of water-crane above rails	9 ft. 6 in.

Locomotive Sheds.

Engine pits, in depth, from	2 ft. 6 in. to 3 ft. 6 in
Minimum height of water tanks above rails	17 feet.
" " engine doorways	15 ft. 9 in.
" width of "	11 feet.
" height of the beams from rails	19 feet.

Carriage Sheds.

Minimum distance of rail, centre to centre	14 ft. 6 in.
" height of doorways	13 feet.
" width of "	11 feet.

Locomotives.

Maximum wheel base of engines, with curves 2,000 ft. radius.	15 feet.
" " " " 1,500 "	13 feet.
" " " " 1,000 "	11 feet.
Bogie frames, with curves under 1,000 feet radius	——
Maximum load on one axle	12½ tons.
Minimum play of flanges of wheels	⅜ inch.
" clear space between wheels	4 ft. 5½ in.
Maximum projection of flange below top of rail	1¼ inches.
" width of tyre	6 inches.
Minimum "	5¼ inches.
" diameter of driving wheel for goods engine	4 feet.
" " " passengers' engine.	5 feet.
" " " express engine	6 feet.
" " leading and trailing wheel	3 feet.
Speed of goods train, per hour	16 miles.
Passenger " " from 25 to	33 miles.
Express " "	40 miles.
Maximum pressure in boiler, per square inch	100 lbs.
Proof pressure in testing boilers	150 lbs.
Height of life guards above rails	2 to 2½ in.
Maximum breadth of engine	10 feet.
" height of chimney above rails	15 feet.
Minimum diameter of tender wheels	3 feet.
Maximum breadth of tender	9 feet.
" height of tender above rails	8 feet.

Carriages and Wagons.

Maximum wheel base for curves of 2,000 feet radius	18 feet.
" " " 1,500 "	15 feet.
" " " 1,000 "	12 feet.
Inclination of cone of tyres	1-20
Maximum breadth of tyre	6 inches.
Minimum " "	5 inches.
" thickness of tyre over rail	¾ inch.
" play for flanges	⅜ inch.
Maximum "	1 inch.
Clear width between wheels	4 ft. 5½ in.
Maximum projection of flange from surface of rail	1¼ inches.
Minimum diameter of wheels	3 feet.
" " axle at nave, with 3¾ tons load per axle.	4 inches.
" " " " 5 " " "	4½ inches.
" " " " 6½ " " "	5 inches.

Minimum diameter of axle journal, with 3¾ tons load	2⅝ inches.
" " " " " 5 "	3 inches.
" " " " " 6½ "	3¼ inches.
Length of axle, centre to centre of journal	6 ft. 5½ in.
Maximum length of journal	8 inches.
Minimum " "	5 inches.
Maximum thickness of steel spring plates	½ inch.
Length of carriage springs	5 feet.
" wagon springs	3 ft. 6 in.
Maximum deflection of springs under load	4 inches.
Minimum " " "	2 inches.
" height of break block above rail	5 inches.
Height of centre of buffers above rails	3 ft. 5 in.
Distance of centre of buffers apart	5 ft. 9 in.
" " side chains apart	3 ft. 6 in.
Minimum diameter of buffers	14 inches.
" rounded projection	1 inch.
Maximum breadth of carriage	8 ft. 7 in.
" " wagons	7 feet.
Maximum height of carriages and wagons	12 ft. 4 in.

Memoranda on English Railways.

Parliamentary Regulations for Railways Crossing Roads.

	Turnpike Road.		Public Road.		Occupation Road.	
	ft.	in.	ft.	in.	ft.	in.
Clear width of under bridge or approach	35	0	25	0	42	0
Clear height of under bridge for a width of 12 feet	16	0	.....		.....	
Do., for a width of 10 feet			45	0	.....	
Do., for a width of 9 feet			.....		44	0
Do., at springing	12	0	42	0	.....	
Over bridge. Height of parapets	4	0	4	0	4	0
Approaches. Inclination	4 in 30		4 in 20		4 in 46	
Approaches. Height of fencing	3	0	3	0	3	0

	Narrow. ft.	in.	Broad. ft.	in.
Average formation width, single line	48	0	24	6
" " " double line	30	0	38	0
Average width of top ballast, single line	43	6	45	6
" " " double line	24	6	29	0

Formation slope from centre in cuttings, 1 in 30.
Width of land taken beyond bottom of slope, from 9 to 12 feet.
Ditch with slopes 1 to 1, 1 foot wide at bottom.
Quick mound, 1 foot 6 inches high.
Post and rail fencing posts, 9 feet apart, 3 feet in the ground.
Dimensions of do., 7 feet 6 inches x 6 inches x 3½.
Intermediate posts, 3 feet apart, 5 feet 6 inches x 4 x 1½.
4 rails 4 x 1½.

Board of Trade Regulations for Railways.

Main Line.

Breaking weight of cast-iron girders to be made = permanent load × 3 + moving load × 6.
Wrought-iron bridges must not be strained to more than 5 tons per square inch when loaded with the heaviest engines.
Minimum distance of standing work from the outer edge of rail at level of carriage steps = 3 feet 6 inches in England = 4 feet in Ireland.
Minimum distance between lines of railway = 6 feet.

Stations.

Minimum width of platforms = 6 feet.
" distance of columns from edge of platform = 6 feet.
Steepest gradient recommended for stations = 1 in 300.

Carriages.

Minimum space per passenger = 20 cubic feet.
" area of glass per passenger = 60 superficial inches.
" width of seats = 15 inches.
" breadth of seat per passenger = 16 inches.
" number of lamps per carriage = 2.

Requirements.

Joints of rails to be fished.
Chairs to be secured by *iron* spikes.
Fang bolts to be used at the joints of flat-bottomed rails.

Stations.

Ends of platforms to be ramped not *stepped*).
Signals and distant signals in both directions.
Signals to be weighted to fly to "danger" if wire breaks.
Switch handles to be brought together.
" not to be worked between lines of rail.
Facing points to be avoided.
" where unavoidable, to be furnished with self-acting signal.
Sidings to be supplied with locked chock-block.

Ramapo Wheel and Foundry Co.

Sidings on a gradient falling towards the line to be provided with a blind siding.
Turn-tables to be a safe distance from adjacent lines.
Platforms of bridges protected from fire.
Walls and handrails to be provided on viaducts at stations.
Level crossing gates to be capable of being closed across both road and railway.
Clocks visible at all stations.
Mile posts and gradient boards.
Tunnels and dangerous places protected by telegraph.

REGULATIONS FOR A UNIFORM CODE OF DANGER SIGNALS.

MEMORIAL TO U. S. CONGRESS, BY FRANKLIN INSTITUTE.

Railroad Signaling—Rules concerning Whistle Signals.

The signal for UP BRAKES, shall be ONE sound of the whistle; DOWN BRAKES, TWO sounds of the whistle; to BACK the train, THREE sounds of the whistle. In case of CATTLE on the track, and on approaching CROSSINGS and curves, there shall be ONE LONG sound of the whistle.

To call in FLAGMEN, or crew of the train, ONE long sound of the whistle.

On approaching STATIONS, ONE long sound of the whistle.

For employés of the road to go to the assistance of a train, THREE long sounds of the whistle.

Bell Signals.

The engine-bell shall be rung on starting the train from all stopping places.

Signals to the Engineer.

To START the train, ONE sound of the gong-bell.
To STOP the train, TWO sounds of the gong-bell.
To BACK the train, THREE sounds of the gong-bell.
To SLACKEN speed, THREE sounds of the gong-bell.

Flag Signals—To Signal Trains during the Day-time.

To indicate "DANGER," a RED FLAG shall be used.

To indicate "CAUTION," a BLUE FLAG shall be used.

To indicate "ALL RIGHT," a WHITE FLAG shall be used.

When an EXTRA train is following on the same time-schedule, TWO RED flags shall be carried on the front of the engine of the preceding train.

When an EXTRA train is following, which shall keep away from all trains, TWO BLUE flags shall be carried on the front of the engine of the preceding train.

Two RED flags shall be placed on the rear end of the last car of every day-train, to enable the engineer to see that all the cars are securely coupled.

Lantern Signals—In Signaling to the Trains during the Night-time.

To STOP the train, or to indicate "DANGER," and at all flag stations and crossings at grade, a RED LIGHT shall be used.

To indicate "CAUTION," a BLUE LIGHT shall be used.

To indicate "ALL RIGHT," a WHITE LIGHT shall be used.

When an EXTRA train is following on the same time-schedule, TWO RED lights shall be carried on the front of the engine of the preceding train.

When an EXTRA train is following, which will keep away from all regular trains, TWO BLUE lights shall be carried on the front of the engine of the preceding train.

Two RED lights shall be placed on the rear end of the last car of every night train, to enable the engineer to see that all the cars are securely coupled.

Motion Signals:

To START the TRAIN, ONE ARM held at right angles to the body.

To STOP the TRAIN, BOTH ARMS held at right angles to the body.

Generally, all VIOLENT MOTIONS made by any person to a moving train, shall be interpreted as signals to STOP.

Detonating signals, or torpedoes placed upon the track, shall be interpreted to designate "DANGER."

OPERATION OF LOCOMOTIVES AND CARS.

Gold Rating at 135.

PERFORMANCE OF LOCOMOTIVES AND COST PER MILE RUN.

Pittsburgh, Fort Wayne, and Chicago Railway Co., Eastern Division.

Total number of miles run	2,584,931	
Number of miles run to one ton of coal	43.10	
" " one quart of oil	29.92	
" " one pound of waste	43.1	
Cost of mile run for repairs	8.31	cents.
" " fuel	5.74	"
" " stores	1.25	"
" " engineers, firemen, and cleaners	7.37	"
Total cost per mile run	22.67	"

Illinois Central Railway—Locomotive Report—Cost per Mile Run, March, 1868.

Oil, waste, and tallow, in cents	.75
Repairs	16.85
Fuel	7.67
Wages	6.35
Cleaning	1.47
Total cost per mile run, in cents	33.09
Average miles run to one cord of wood	43.98
" " one ton of coal	39.87
" " one pint of oil	13.83
Average number of cars per train	10.83

Two empty cars rated as one loaded one.

Average cost per mile, in cents, for passenger engines	20.10
Freight engines	35.42
Construction	29.97
Switching	18.51

Philadelphia and Reading R. R., 1867.

Miles run by 268 locomotives	4,356,385
Total number of tons of 2,000 lbs., hauled 1 mile, including weight of cars, but exclusive of engine and tender	997,152,429
Average weight of loaded coal trains down, exclusive of engine and tender	779.0
Average weight of empty coal trains up	266.6
Average weight of passenger trains	76.2
Average cost of repairs of locomotives per mile run, in cents	13.52
Average cost of repairs of locomotives per ton of 2,000 lbs., hauled 1 mile, in cents	.05907

Distribution of Cost of Repairs of Locomotives.

Wages of mechanics	62	per cent.
Materials—iron, steel, brass, etc.	31	"
Superintendence, paints, tools, etc.	7	"
	100	"

COAL AND FREIGHT CARS.

Average cost of renewals and repairs per car per annum—all cars estimated as 4-wheel cars	$45 10
Cost of repairs per ton of load of 2,000 lbs., carried 1 mile, in cents	.01498

Distribution of Cost of Repairs of Coal and Freight Cars.

Wages of mechanics	60	per cent.
Timber, iron, steel, and all metals	32	"
Superintendence, tools, paints, oils, etc.	8	"
	100	"

PASSENGER CARS.

Number of cars	110
Average cost of annual renewals and repairs	$601 33
Cost of repairs per passenger carried 1 mile, in cents	.2055

Distribution of Cost of Repairs.

Wages of mechanics	54	per cent.
Timber, iron, steel, and metals	33.5	"
Superintendence, tools, paints, etc.	12.5	"
	100.0	"

COST OF RUNNING PASSENGER TRAINS.

Report of Philadelphia and Reading Railroad Co.

Items of Cost, in detail, of running Passenger Trains on the Philadelphia and Reading R. R., for the year ending Nov. 30, 1867, using Anthracite Fuel, per Daily Trip of 93 miles.

Items of Cost.	No.	Description.	Average Rate.	Amount.
Wages of engineer	1	Day.	.....	$3 48
" fireman	1	"	.....	2 25
" conductor	1	"	.....	3 88
" baggage master	1	"	.....	2 24
" brakeman	2.7	"	$1 86	5 02
Coal for fuel	2.07	Tons.	3 15	6 52
Wood for kindling	.16	Cords.	5 79	93
Water used	4	M. galls.	07	28
Oil for engine and tender, including lamps	.58	Galls.	1 03	60
Oil and grease for cars	..	Trip.	.....	32
Repairs of engines	93	Mile.	$13\frac{5}{100}$	12 14
" and refitting cars	..	Trip.	.....	10 41
Hands at depots, extra engines, etc.	..	"	.....	7 46
Sundries for trains, and all other charges	..	"	.....	5 14
				$60 67

Equal to 111.4 *cents per through passenger, at* 54.47 *passengers per train*, or 1.198 cents per mile per passenger.

Cost of Running Freight Trains.

Philadelphia and Reading R. R., for the year ending Nov 30, 1867.

Per Daily Trip of 93 miles, transporting average loads of 232.8 tons, and average through loads of 105.1 tons of merchandise, 2,000 lbs. each.

Items of Cost.	No.	Description.	Average Rate.	Amount.
Wages of engineer	1	Day.	.....	$3 68
" fireman	1	"	.....	2 31
" conductor	1	"	.....	2 45
" brakeman and signalman	3	Days.	$2 32	6 96
Coal for fuel	3.31	Tons.	3 15	10 43
Wood for kindling, etc.	.18	Cords.	5 79	1 04
Oil and tallow for engine and tender	..	Trip.	.....	1 05
Oil and grease for company's cars	..	"	.....	44
Water used	7	M. galls.	07	49
Repairs of engine and tender	93	Miles.	$14\frac{63}{100}$	13 61
" company's cars	..	Trip.	.....	28 51
Depot hands and depot expenses	..	"	.....	18 33
Renewals of sundry articles, goods damaged, etc.	..	"	.....	5 53
				$94 83

Equal to 40.73 cents per ton, or 00.22 cents per ton per mile.

93 *miles.*

Ramapo Wheel and Foundry Co.

Cost of Hauling Coal Trains,

On the Philadelphia and Reading R. R., for the year ending Nov. 30, 1867.

Per Round Trip of 190 miles, from Coal Region to Tide-water and back, with empty cars, transporting average loads of 516.9 tons, and average through loads of 458.3 tons of coal of 2,240 lbs. each.

Items of Cost.	No.	Description.	Average Rate.	Amount.
Wages of engineer	2	Day.	$3 66	$7 32
" fireman	2	"	2 46	4 92
" conductor	2	"	2 47	4 94
" brakemen and signalmen	6	"	2 38	14 28
Anthracite coal for fuel	9.05	Tons.	3 15	28 51
Oil for engine and tender and lamps	1.24	Galls.	1 03	1 28
Oil and grease for company's cars	.	Trip.	....	3 56
Repairs of engine and tender	190	Miles.	11 $\frac{9}{10}$	22 62
" company's coal cars	..	Trip	.....	79 92
Supplying water	18	M. galls.	.07	1 26
Wood for kindling, etc	.25	Cords.	5 79	1 45
Assistant engines at Fall's grade	458	Tons.	00 $\frac{78}{100}$	3 57
Car couplers, time-keepers, despatchers, and all other contingent expenses	458	"	3 47	15 89
				$189 52

Equal to 36.66 *cents per ton, or* 41.35 *cents per ton carried through* 95 *miles.*

Statement of Expenses for Locomotive Power, Repairs of Cars, etc.,

For one year ending March 31, 1868, *on the* Atlantic and Great Western Railway—6 *feet Gauge. Length of Road and Branches*, 507 *miles.*

Whole number of engines	153
Total days' service of engines	34,474
" miles run	3,289,639
Number of cars hauled one mile	40,372,938
Price of wood per cord	$4.09
" coal per ton	2 89
Quarts of head light and lamp oil used	28,898
" lubricating oil	87,333
Pounds of tallow	99,663
" waste delivered to engines	24,609
" " " wipers	34,104
Cost of fuel consumed per mile run by locomotive, cents.	10.94
" oil, tallow, and waste " " "	1.06
" repairs " " "	11.65
" small stores " " "	0.24
" wages, enginemen and firemen, per mile run by locomotive, cents	6.91
" cleaning per mile run by locomotive, cents	1.48
" watching, despatchers, and all others at engine-houses, cents	1.02
" wooding, coaling, etc., cents	1.25
Total cost of locomotive power, in cents	34 55
Pounds of fuel consumed per mile	55.94
Miles run to one pint lubricating oil and tallow	12.00
Average number of miles run per day's service, passenger and freight trains	101.28
Average number of miles run per day's service, all trains.	95.42
" " " by each engine per month.	1,791 70
" " cars per trip	12.27
" " passenger cars per trip	4.05
" " freight " "	17.48

Total cost of hauling each car per mile, all trains, in cents..... 2.81
Total cost of hauling passenger and freight cars per mile, in cents..... 2.38
Passenger car mileage..... 3,061,308
Freight " " 33,412,871
Mileage of all cars.....40,372,938
Cost per mile repairs of passenger cars, in cents..... 4.49
" " freight " " 0.69
Average cost per mile, repairs of all cars, " 0.94
Miles run to one pint of oil, passenger cars..... 49 80
" " " freight cars.....181.40
Total miles run to one pint of oil, all cars.....144.80
Total quarts lubricating oil used for cars.....139 301
Cost of oil per mile, passenger cars, in cents..... 0 112
" " freight " " 0.025
" " all cars, " 0.033

Wood consumed reduced to a coal basis, 8,000 *pounds of coal to* 7 *cords* (128 *cubic feet each*) *of wood.*

Pennsylvania Railroad, 1867.

Average mileage of locomotives with passenger trains... 22,526
" " " " freight " ... 21,096
" greatest mileage of passenger locomotives..... 40,794
" " " freight " 34,834

Total average cost for 2 years (1866, 1867), per 100 miles run, was—

For repairs.....$12 98
" fuel..... 8 54
" stores 2 07

Totals in currency (gold 135).....$23.59

Average consumption of fuel per mile run, 66 75 lbs bituminous coal, including wood for kindling, rated at 1½ cords of wood to 1 ton of coal.

Maintenance of pass. cars per locomotive train mile, cts. 24.80
" freight " " " " 17.115

SUMMARY OF COST OF OPERATION OF RAILROADS IN STATE OF NEW YORK FOR 1866.

Deduced from Report of State Engineer.

Average expense was 75.99 per cent. of all the earnings.

Of which, cost of Maintenance of Way was	33.04	per cent.
" " Repairs of Machinery was	21.58	"
" " Operating the Roads	45.38	"
	100.00	

MAINTENANCE OF WAY, as follows:

Total cost for road-bed and way, exclusive of iron	43.14	per cent.
" of iron for repairs	29.59	"
" of repairs of buildings	10.38	"
" " fences and gates	0.14	"
Taxes on real estate	11.02	"
Other costs not allotted	5.73	"
	100.00	

REPAIRS OF MACHINERY, as follows:

Engines	41.8	per cent.
Cars	44.8	"
Tools, &c	4.1	"
Incidental expenses, oil, fuel, &c	3.7	"
Other costs not allotted	5.6	"
	100.0	

OPERATING THE ROADS, as follows:

Office expenses and stationery	2.22	per cent.
Agents and clerks	8.67	"
Labor, unloading freight	8.79	"
Porters, watchmen, and switchmen	5.48	"
Wood and water-station attendance	1.09	"
Conductors, baggagemen, and brakemen	9.35	"
Engineers and firemen	10.16	"
Fuel, cost and preparing	32.22	"
Oil and waste for engines and tenders	3.85	"
" for cars	0.90	"
Loss and damage on goods and baggage	2.02	"
Injuries to persons	0.86	"
Damage of property and cattle killed	0.74	"
General superintendence	2.17	"
Contingencies	10.14	"
Other costs not allotted	1.41	"
	100.00	

Average cost, per mile of road, for maintaining roadway	$4,577 35
" " " for repairs of machinery	2,991 70
" " " for operating road	6,287 34
" per mile of single track, for maintaining roadway	2,789 82
" " " for repairs of machinery	1,823 40
" " " for operating road	3,832 04

Equipment.

1 locomotive to the equivalent of	4.37	miles of single track.
1 first-class passenger car to the equivalent of	5.18	" "
1 second-class " " "	12.82	" "
1 baggage car " "	14.92	" "
3 57-100 freight cars, per equivalent of mile of single track.		

Passenger Business.

Average rate of speed of ordinary trains, including stops	20.84 miles.
" " same when in motion	26.34 "
" " express pass. trains, inc'ding stops.	27.58 "
" " same when in motion	31.99 "
Weight in tons of passenger trains, exclusive of passengers and baggage	79.38
Average number of miles travelled by each passenger	37.44
" " passengers in each train	69.72
Aggregate movement of passenger trains is equivalent to passing over the road	3,898 times.
Average sum received for carrying one passenger one mile	2.42 cents.
" cost per mile for carrying each passenger	1.863 "
" number of miles of travel for each passenger killed	40,203,823
" number of miles of travel for each passenger killed or injured	6,387,523
" number of passengers carried for each one killed	1,073,804

Freight Transportation.

Average rate of speed of freight trains, including stops	11.82 miles.
" " when in motion	15.27 "
" weight in tons, exclusive of freight	149.00
" number of miles each ton of freight was transported	113.95
" " tons in each train	74.85
Aggregate movement of freight trains is equivalent to passing over the road	5,570 times.
Average sum received for transporting one ton of freight one mile	2.853 cents.
Average cost per mile for carrying each ton of freight	1.952 "

OPERATION OF RAILROADS.

As the cost of operating railroads differs materially, owing to location, etc., the following data may be useful for comparisons:

COST OF OPERATION OF PENNSYLVANIA R R. CO., 1867.

Total expenditures, $12,080,299.64; total receipts, $16,340,-156 36. Percentag of distribution of total expenditure was—

	Passenger.	Freight.	Total.
For conducting transportation...	8.10 per ct.	20.93 per ct.	29.03 per ct.
" motive power	6.06 "	20.92 "	26.98 "
" maintenance of cars..... ...	4.13 "	8.53 "	12.66 "
" general expenses....	0.46 "	1.05 "	1.51 "
Totals.....	27.70 "	72.30 "	100.00 "

Receipts—Passenger, mails, and express....	24.69 per ct. of total receipts.		
" Freight traffic.....	72.41	"	" "
" Miscellaneous sources.....	2.90	"	" "
	100.00	"	" "

OPERATION OF PHILADELPHIA AND READING R. R., COAL ROAD,

For year ending Nov. 30, 1867. *Gold*, 135.

Tons of coal hauled 1 mile.....		=	360,295,752
" merchandise hauled 1 mile		=	49,796,302
Tonnage of coal hauled, of	2,240 lbs.....		3,446,826
" merchandise "	2,000 "		1,185,896
" materials "	2,000 "		242,526
" passengers "	2,000 "		546,290
Total tonnage of road.....			5,421,538

Receipts and Expenses per Passenger and per Ton.

Per passenger, cost	$1 81 7-10	Received..	$2 91 8-10
Merchandise, per ton.....	64 8-10	" ...	1 28 6-10
Coal	94 9-10	" ..	1.85 8-10

Gross receipts from coal	= 70.33	per ct. of total receipts.	
" " " mdse	= 16.75	"	"
" " pass., mails	= 12.92	"	"
	100.00		

Ramapo Wheel and Foundry Co.

Total expenses = 68.81 per cent. of total receipts.

Of the expenses—

Transportation was	57.88	per ct.
Roadway	17.43	"
Dumpage, rents, taxes, profit and loss	16.36	"
Renewal fund	8.33	"
	100.00	

Of transportation expenses—

Running account	44.37	per ct.
Workshop "	43.33	"
Depot "	6.68	"
Superintendence account	4.18	"
Office "	1.44	"
	100.00	

RUNNING ACCOUNT = 44.37 per cent. of transportation expenses. Running expenses as follows:

Wages of all engineers, conductors, firemen, brakemen, etc.	59.27	per ct.
Wood for fuel	1 97	"
Loading, unloading, and cutting wood	1.30	"
Oil	6.73	"
Tallow, lard, grease, and cotton waste	2 45	"
Coal—fuel for locomotive engines	25.60	"
Expenses of magnetic telegraph	1.46	"
Sundries	1.22	"
	100.00	

WORKSHOP ACCOUNT = 43.33 per cent. of transportation expenses. Workshop account as follows

Wages of all machinists, blacksmiths, carpenters, mechanics, and shop hands	62.21	per ct.
Bar iron, steel, blooms, etc.	8.22	"
Iron castings	6 94	"
Copper, spelter, tin, lead, etc.	2.15	"
Timber and lumber	5.07	"
Anthracite coal for shops	0.61	"

Bituminous coal	0.49	per ct.
Hardware, files, tools, paints, wire rope	5.89	"
Wheels for cars, engines, tenders	4.51	"
Axles " " "	2.37	"
Tires for engines	0.93	"
Sundries	0.61	"
	100.00	

DEPOT ACCOUNT = 6.68 per cent. of transportation expenses.

Wages of all hands at stations	52.48	per ct.
" watchmen at depots and switchers	19.17	"
" " signal towers	11.99	"
Pumping water and sundry expenses	16.36	"
	100.00	

SUPERINTENDENCE ACCOUNT = 4.18 per cent. of transportation expenses.

Salaries of all officers, clerks, and agents	4.18	per ct.

OFFICE ACCOUNT = 1.44 per cent. of transportation expenses.

Stationery, printing, advertising, furniture	1.44	per ct.

Of Maintenance of Roadway.

Repairs and renewals of track	69.42	per ct.
Bridges	5.42	"
Buildings	6.75	"
Machinery	5.58	"
Wharves	6.14	"
Police	3.51	"
Sundries	3.19	"
	100.00	

Distribution of Repairs and Renewal of Track.

Average cost per mile for 770 6-10 miles single track, $960.68.

Raising and repairing track, per mile	$330 84
Ballast broken stone	34 64

Ramapo Wheel and Foundry Co.

Clearing side ditches	$29 00
Walls and embankments	21 30
344 4-10 sills, per mile	217 84
Timber and lumber	38 77
Spikes and nails	28 88
Chairs	33 51
Frogs	42 22
Switches	38 13
Sidings and coal chutes	78 82
Tools and hardware	25 17
Extraordinary repairs—freshet	28 56
Oil and sundries	13 00
	$960 68

Repairs and renewals of bridges per mile of road	75 05
" " buildings " "	93 65

For cost of operation of locomotives, cars, hauling trains, etc., see "Operation of Locomotives and Cars."

Operation of the Atlantic and Great Western Railway,

Year ending March 31, 1868. *Gold rated at* 135.

Working expenses were.....61 80-100 per ct. of the earnings.
Renewal " " .....14 33-100 " " "
The expenses and renewals... 76 14-100 " " "

Expenses divided as follows:

			Cost per mile operated.
To office and station expenses..	8.23	per ct. of total..	$514 14
" cost of running	33.82	" "	2,114 39
" general expenses	6.76	" "	422 12
" repairs of engines and cars	25.89	" "	1,617 97
" " track and roadway	13.88	" "	867 63
" " structures	.89	" "	55 50
" incidentals	3.99	" "	249 62
" miscellaneous	6.54	" "	408 80
	100.00		$6,250 17

Renewals.

To passenger, baggage, and mail cars	0.59	per ct. of total		$3 52
" freight cars	1.48	"	"	21 46
" track	93.89	"	"	1,360 37
" fences and gates	1.27	"	"	18 44
" bridges	2.76	"	"	40 03
" buildings	.01	"	"	04
	100.00			

Percentage of Repairs on Cost of Rolling Stock.

Repairs of locomotives and tenders	11.533	per ct.	upon cost.
" pass'ger, baggage, and mail cars	16.25	"	"
" freight cars	6.848	"	"

Total tons of freight moved	1,738,522
at $2.96 per ton, or 2.19 cts. per ton per mile.	
Total miles hauled	180,684,634
" number of passengers	715,867
" miles hauled	30,114,023
Average distance passengers carried	42.07 miles.
" rate per mile, in cents	3 09

Distribution of Employes.

General offices	68
Stations, agents, clerks	512
Wood and water stations	48
Conductors, baggagemen, and brakemen	512
Enginemen and firemen	301
Repairs of track and roadway	1,127
" bridges and buildings	37
Machine shops	668
Car shops	338
Rail repair shop	39
Miscellaneous	71
Total	3,721

Ramapo Wheel and Foundry Co.

Total number of miles of road operated	506
Average number of men per mile	7⅓
" wages per man per month	$46 83
" " mile of road operated	343 69

TONNAGE OF RAILROADS, 1867.

State of New York	3,501	tons to 1 mile of road.
" Massachusetts	3,853	" " "
" Pennsylvania	7,864	" " "
Average of three States	5,826	" " "
" all railroads in U. S.	2,000	" " "

Relative Proportions of Several Classes of Tonnage on Railroads, State of New York,

For 10 years, 1858 to 1867, inclusive.

Classes of Tonnage.		Av. Value of Tonnage, by Classes.
Products of the forest	7.85	0.60
" animals	17.99	31.60
Vegetable food	18.78	5 00
Other agricultural products	5.02	8 70
Manufactures	10.62	3.44
Merchandise	14.80	47.45
All other articles	24.94	3.21
	100.00	100.00

Average Value per Ton of all Classes,

From 1858 to 1867.

1858	$100 25	1863	$155 97
1859	122 81	1864	181 31
1860	125 92	1865	212 11
1861	109 17	1866	179 14
1862	129 90	1867	139 63

The tonnage of the Pennsylvania R. R. in 1868 was 4,722,015 tons, or 3,968 tons per mile of single track, including sidings and branches, or 5,400 tons per mile for the equivalent of the main line. Average charge on freight was 1 906-100 cents per net ton per mile. Cost of transportation was 68 8-10 per cent. of the receipts. The number of tons of freight carried on the railroads in the United States in 1868 may be estimated at 2,000 tons per mile. Total tonnage of merchandise moved may be taken at 48,488,000 tons, which at $150 per ton, gives total value of goods moved on all roads equal to $7,273,200,000, or a sum four and a half times greater than their aggregate cost, and 22 times greater than their gross income.

The gross increase of tonnage in 10 years, on the N. Y. Central, Erie, and Pennsylvania railroads, from 1857 to 1867, has been nearly 300 per cent., while the increase of tonnage of the whole United States, which in 1851 was 10,000,000 tons, deducting duplications say 1,000,000 tons, and coal and cheap products say 3,000,000 tons, gave total merchandise moved as 6,000,000 tons, as compared with 48,488,000 tons in 1867, or an increase of 800 per cent. The increase in value of merchandise tonnage in 16 years (taken at $150 per ton) has been $6,373,200,000, or more than $600,000,000 annually. One-half of this increase has been since 1861.

THE RATIO OF MILEAGE OF RAILROADS to population of the United States in 1840 was 1 mile to 7,415 people; in 1850, was 1 to 3,298; in 1860, was 1 to 1,083; in 1867, was 1 to 905; in 1870, population estimated as 37,-680,000, miles of railroad 45,000, or 1 mile to 837 inhabitants. The States composing the Union have an area equal to 1,940,728 square miles. A railway mileage equal to the ratio of Ohio, or 1 to 11 7, would give an aggregate equal to 165,800 miles. A ratio equal to that of Massachusetts would give 352,860 miles.

THE AVERAGE COST of the railroads in the United States may be taken at $41,000 per mile. Those of New England at $40,500 per mile; Middle States, $53,000; Western States, $41,000; Southern States, $30,000. Total aggregate cost, $1,600,000.

RAILROAD EARNINGS, 1867.—State of New York, $15,000 per mile; Pennsylvania, $12,600; New England, $12,927; Western, $10,000 to $16,000. Aggregate earnings of the Eastern, Middle, Western, and Pacific States, $10,000 per mile, or a total of $291,460,000; the earnings of the Southern railroads, at $5,000 per mile, for 10,000 miles, or a total of $50,000,000—the total earnings of all railroads in the United States in 1867 being $340,000,000.

The ratio of gross earnings to cost for the whole country, will be about 21 per cent.; for the Northern States, 23 per cent.

Ramapo Wheel and Foundry Co.

STATEMENT of Tonnage Carried over the Specified

	Boston and Worcester.	Western.	New York Central.	Erie.	Hudson River.	New York and Harlem.	Pennsylvania.	Delaware, Lackawana, and Western.	Philadelphia and Reading.
1858..	322,519	437,896	765,407	816,965	160,197	122,371	1,046,889	.....	1,730,426
1859..	327,350	448,345	834,319	869,072	258,965	145,577	1,170,240	.....	1,967,541
1860..	352,999	505,547	1,028,183	1,139,554	337,852	153,511	1,346,525	.....	2,377,883
1861..	345,174	508,179	1,167,302	1,253,419	370,098	168,527	1,620,586	.....	1,964,493
1862..	382,494	587,504	1,387,433	1,675,234	577,740	198,667	2,223,051	1,316,892	2,934,221
1863..	413,731	663,927	1,449,604	1,874,634	656,967	233,981	2,454,876	1,510,405	3,951,595
1864..	458,320	692,860	1,557,148	2,214,295	601,824	236,467	2,764,876	1,621,364	4,115,591
1865..	427,404	693,754	1,275,299	2,175,965	491,855	239,603	2,798,810	1,200,097	4,186,782
1866..	549,319	884,504	1,602,197	2,871,505	497,397	298,206	3,452,718	1,920,874	4,978,701
1867..	597,400	934,605	1,667,926	3,484,546	581,437	264,428	4,000,538	2,140,134	4,855,248

Railroads Yearly, from 1858 to 1867, inclusive.

Philadelphia, Wilmington, and Baltimore.	Cleveland, Columbus, and Cincinnati.	Pittsburg, Fort Wayne, and Chicago.	Michigan Central.	Michigan Southern.	Illinois Central.	Chicago and Alton.	Chicago, Rock Island, and Pacific.	Chicago, Burlington, and Quincy.
.....	296,025	285,663	235,123	261,613	381,568	.....	201,068	.....
.....	286,209	362,606	295,276	346,300	422,433	.....	.....	.....
.....	296,835	465,204	378,570	398,679	490,343	.....	.....	.....
165,352	416,756	526,379	463,112	452,708	720,868	.....	301,669	734,573
175,972	571,087	643,107	564,827	543,626	806,685	.....	285,144	835,563
217,034	607,063	805,525	542,410	558,979	952,814	.....	379,879	777,736
240,298	562,758	858,928	485,275	527,501	1,022,024	386,197	441,510	809,674
235,930	459,703	832,615	533,451	569,340	1,034,946	511,012	472,557	737,511
260,294	517,199	1,025,778	578,177	679,765	1,153,175	636,360	459,986	821,883
243,361	570,101	1,154,351	638,586	735,438	1,300,835	750,657	598,714	971,374

Ramapo Wheel and Foundry Co.

RAILROADS OF THE

STATEMENT *showing the Length of Line in Use and the Equipment thereon and the Cost,*

Years ending Sept. 30.	MILES OF RAILROAD.			EQUIPMENT.				COST OF ROAD, ETC.		Distance Run by Locomotives hauling Train.	PASS'R
	Main Line and Branches.	Second Track and Sidings, etc.	Total Equivalent Single Track.	Engines.	CARS. Passenger.	Baggage, Mail, and Express.	Freight.	Amount.	Per Mile.		Number of Passengers.
1858..	2,516	937	3,353	738	877	239	9,012	$134,971,832	$53,646	11,563,318	11,250,073
1859..	2,527	1,007	3,534	748	822	234	9,241	136,455,473	53,999	11,869,778	12,138,059
1860..	2,566	1,033	3,599	748	822	248	9,438	139,571,616	54,392	12,875,145	9,305,978
1861..	2,658	1,062	3,720	755	867	244	9,592	144,718,732	54,449	14,031,926	8,684,189
1862..	2,710	1,079	3,789	769	834	242	10,639	148,318,179	54,730	15,349,873	8,707,789
1863..	2,729	1,096	3,825	799	898	245	11,115	151,289,901	55,434	16,611,861	10,291,813
1864..	2,787	1,141	3,908	814	859	259	12,729	158,691,317	57,387	18,674,856	13,442,324
1865..	2,835	1,184	3,989	962	1,001	292	15,284	167,318,492	59,026	21,012,056	15,976,815
1866..	2,891	1,238	4,079	1,002	1,188	294	15,313	171,689,508	59,387	23,808,394	16,886,987
1867..	2,955	1,293	4,248	1,075	1,114	352	16,525	182,015,750	61,595	21,012,056	17,377,465

STATE OF NEW YORK.

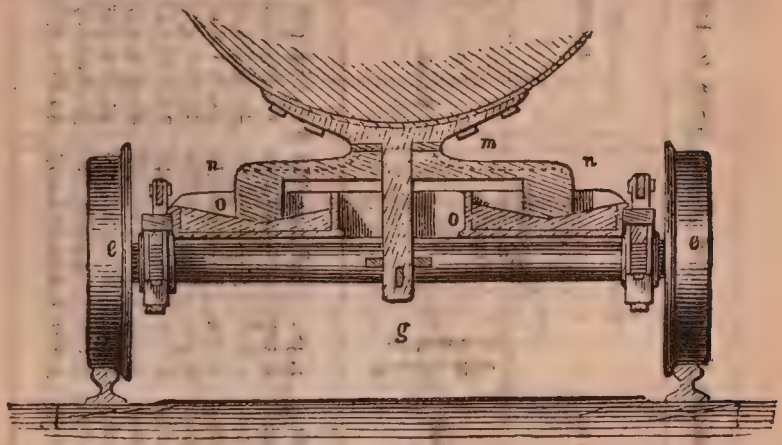
together with the General Results of Operations for the Ten Years, 1858 *to* 1867, *inclusive.*

TRAFFIC.		FREIGHT TRAFFIC.				EARNINGS.		
Passengers carried One Mile.	Passengers to Mile of Road.	Tons of Freight.	Tons carried One Mile.	Tons to Mile of Road.	Aggregate Value of Freight.	Gross.	Net.	Expenses per cent.
373,159,179	4,471	3,473,725	420,604,609	1,381	348,247,661	$18,664,486	$6,846,697	63.32
370,989,486	4,803	3,859,283	433,425,441	1,527	473,940,233	18,363,034	7,273,483	60.39
382,985,206	3,626	4,741,773	564,050,505	1,848	597,110,410	20,477,599	7,824,923	61.75
337,954,686	3,269	5,460,409	660,556,875	2,054	596,139,133	21,211,242	7,445,176	64.90
344,260,277	3,213	6,506,135	821,160,067	2,401	844,165,862	25,722,473	10,502,286	59.17
428,568,394	3,771	7,197,804	931,569,125	2,637	1,122,458,340	32,396,743	12,963,809	59.98
586,150,730	4,859	8,143,562	944,657,060	2,943	1,476,530,038	40,494,437	12,645,964	68.77
721,554,853	5,956	7,388,852	859,716,361	2,606	1,567,222,210	47,815,535	10,209,233	78.86
710,897,620	5,841	9,210,486	1,059,863,237	3,186	1,649,988,140	50,249,227	12,373,085	75.38
656,524,676	5,881	10,343,681	1,192,818,673	3,501	1,444,373,495	49,661,572	14,787,399	70.23

Ramapo Wheel and Foundry Co.

LOCOMOTIVE ENGINE SAFETY TRUCK.

Among the recent inventions for the improvement of the locomotive, in its relation to the permanent way, the swing motion represented in the cut, or the same invention when applied with a radius bar, must take high rank.

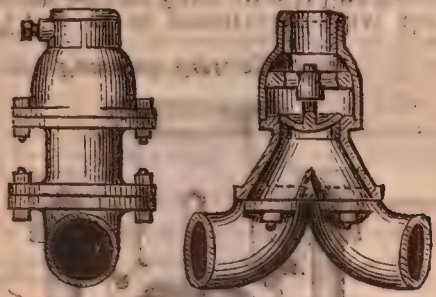


The "SAFETY TRUCK" is simple in construction and easily applied to any engine, old or new. It permits the use of flanges on all wheels, and causes the driving wheels to keep their true position on straight lines, and to run freely on all curves WITH THEIR AXLES NEARLY PARALLEL TO THE RADIAL LINE, precisely in the same manner as those of an ordinary car truck, thus entirely removing the constant and forcible tendency of the "Drivers" to thrust the truck wheels against and over the outer rail of curves; and while all undue friction on the driving wheels and its consequent wear of TIRES and RAILS is prevented, the net power of the engine is correspondingly increased and the greatest degree of safety insured.

In cases of run off, from broken rails, etc., on embankments and along streams, the truck being prevented from turning to a right angle under the engine, has proved itself of great value in saving life and loss of property.

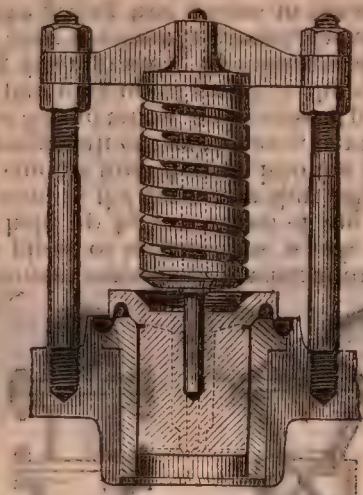
When desirable to do so, the "SAFETY TRUCK" is constructed with two wheels only, still possessing all the functions and useful qualities of a four-wheeled truck. This modification has proved valuable for freight engines having more than four driving wheels. The inventions combined in these improvements are from the following "Letters Patent," granted to Levi Bissell, dated August 4, 1857, and November 2, 1858; D. R. Pratt, dated October 16, 1860; Alba F. Smith, dated February 11, 1862, and to Wm. S. Hudson, dated April 5, 1864, and May 10, 1864. It has been adopted, after thorough trial, in more than sixty railways in America, and is in use in most foreign countries. Mr. ALBERT BRIDGES, No. 46 Cortlandt street, New York, is the authorized agent for the company.

T. S. DAVIS' IMPROVED EXHAUST VALVE.



This improvement consists in placing automatic conical valves in the exhaust pipes of locomotives, which, when the engine is in motion, are held up by the action of the exhaust, and fall to their place as soon as the stream is shut off, thereby effectually preventing all cinders from flowing into the cylinders and valve-chests, doing away with cut valve seats, bent piston rods, diminishing the use of oil and tallow, and excess of pressure in the boiler, caused by the pumping up of air while the steam is shut off and engine running down grade. By indicator diagrams, Mr. Davis shows that no back pressure is caused, the annular enlargement around the valve giving free access to the escape of the steam. The simplicity of the invention, and the great objects to be gained, will doubtless commend it to the attention of railroad men.

RICHARDSON'S SAFETY-VALVE.



Patented Sept. 25, 1866.

This Safety-Valve is so constructed that the steam acts against it with much greater force after it lifts from its seat than before, and thus effectually overcomes the rapidly increasing resistance of the spring or scales. An ample and free outlet for the steam is by this means promptly and certainly provided at every demand.

The additional points of superiority may be briefly stated as follows:

1st—Its construction is perfectly simple and its application at once easy and inexpensive.

2d—It has no levers nor pins, and so does away with all friction; at the same time it may be used with the ordinary locomotive spring balance.

3d—It will wear longer than any other safety-valve without leaking.

4th—It is impossible to accumulate pressure in the boiler above the number of pounds at which it is set to blow off, although the damper may be open and the blower on. The strain from excessive pressure, so damaging to a boiler and so frequently experienced, is hereby entirely avoided.

5th—When attached to a boiler and adjusted for blowing off at a given point, such adjustment cannot be disturbed without detection. The master mechanic is therefore certain that no boiler is at any time carrying a greater number of pounds of steam than he has determined for its maximum limit.

6th—It can be so fitted as to close down uniformly and securely at any point between 4 and 12 pounds below the blowing-off point.

7th—It is as accurate as any steam-gauge can be made, and is less liable to get out of order.

Its successful working in every respect is proving it to be an indispensable attachment to steam boilers.

This valve having been adopted by the Erie, N. Y. Central, and Pennsylvania railroads, as the standard safety-valve, requires only to be seen and tried to prove its merits.

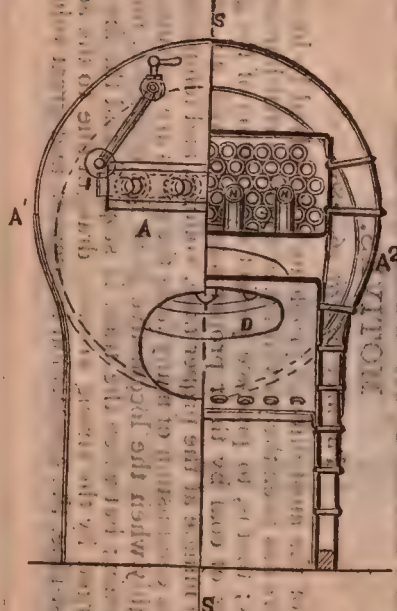
W. Buchanan's and J. M. Toucey's

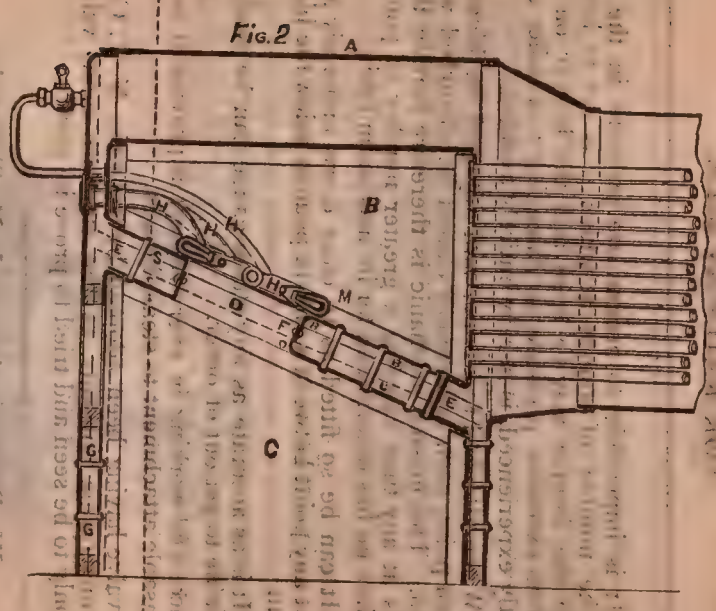
IMPROVEMENT IN FIRE-BOXES OF LOCOMOTIVES.

Patented March 26, 1867.

One of the most difficult problems to be solved by locomotive engineers has been the prevention of smoke in coal-burning locomotives; that is, to produce perfect combustion of the gaseous products of coal by their proper admixture with air, to cause them to mingle at the proper time, volume, and temperature.

In the combustion of many fuels the gases are consumed very thoroughly when the locomotive is in full operation, moving a heavy train; but when the train is stopped, and the fire ceases to be urged by the strong artificial draught due to the action of the blast-pipe, the combustion is sluggish, and great volumes of





W. Buchanan's and J. M. Toucey's Improvement in Fire-Boxes of Locomotives.

carbonic oxide and opaque matter emitted from the stack, incommode the attendants and passengers.

Air, without pressure, will not enter in sufficient volume to complete combustion; with *this improvement* air is freely admitted, entering into the upper portion of the furnace with great force, and consuming the gases; the draught through the incandescent fuel is slow, allowing ample time for evolving all the gases, and the engine is able to run at all times with larger exhaust openings than in the ordinary boiler.

The gases having no means of escaping without meeting the currents of air, a perfect combustion takes place, resulting in great economy of fuel and freedom from smoke. After a trial of two years on the Hudson River Railroad, the wear of the fire-boxes and parts has been less than with the ordinary furnace, and saving in fuel as follows:

Result of Experiment with Patent Fire-Box, as compared with ordinary Fire-Box—both engines 17-inch cylinder, 24-inch stroke, driving-wheels 5 feet 6 inches diameter, running through Albany Express, of 8 coaches—time, 4 hours—on opposite trains, the engines, with exception of boilers, being the same, burning same description of fuel, running 12 trips of 146 miles each.

	Coal Used.	Miles Run.	Miles to 1 Ton of Coal.	Lbs. Coal per Mile.
Ordinary Fire-Box.	101,173.3 lbs.	1,752	38.8	57.7
Buchanan & Toucey's Pat. Fire-Box.	84,746.6 "	1,752	46.3	48.3

Figure 1 is a front view partly in section of the fire-box of a locomotive constructed according to our invention; the section being on the line T T in Fig. 2.

Figure 2 is a longitudinal section on the line S S in Fig. 1.

Similar letters of reference indicate like parts in all figures.

A is the exterior shell of the locomotive boiler. B is the upper portion of the fire-box. C is the lower portion. B1 and C1 form respectively the upper and lower faces of the inclined partition which partially divides the

interior of the fire-box, leaving a hole, D, through which the gaseous products of combustion may rise from the incandescent fuel on the grate, and after circulating in the upper portion of the fire-box, may be drawn through tubes and discharged up the stack. E E, etc., are small tubes tapped through the partition B1 C1. E' E' are stays also employed. The lower portion, C, of the fire-box, is by preference made of copper. The upper portion, B, may be made of good iron. The lower portion, whether made of copper or iron, by reason of its being exposed to more intense heat, and more violent alternations of temperature than the upper portion, is soonest burned out or destroyed; and one object of our invention is to provide for the easy removing and replacing of the lower half, C, together with the lower half, C1, of the inclined partition. The periphery of the hole, D, is formed by two broad flanges, *b* and *c*, which extend respectively from the upper and lower faces, B1 and C1, in the manner indicated, and are joined by rivets, F. In order to remove the lower fire-box, C, with the attached parts, C1 and *c*, we cut off the rivets, F, and remove the stays, E E', and the stays G, which connect the lower portion, C, of the fire-box with the external shell, A. The fastenings at the lower edge being also removed, the whole lower portion of the fire-box is lowered out of the boiler; and on applying the new one in the proper position, and inserting new fastenings at all the points referred to, and properly caulking the seams, if necessary, our locomotive is in good condition for use for a long period. There may be two holes, D, instead of one, if preferred. H is a hollow ring, by preference of cast iron, made in two or more parts, properly secured together, and provided with nozzles, *h*, extending radially inward, as represented. H1 H1 are pipes, which lead the external atmosphere from the exterior of the boiler into the hollow interior of this ring, H. I is a slide, fitted in ways, as represented, and adapted to close these passages for the admission of the air, either partially or entirely, when desired. The air admitted through these passages and through the nozzle, *h*, mingles with the hot gases rushing upward through the opening, D, and aid in completing the combustion of the smoke therein. M is an internal pipe, made of strong gas-pipe, or other suitable material, and capable of bearing the full pressure of the steam in the boiler, even when somewhat warped and damaged by occasional exposure to great heat. It is provided with nozzles, *m*, which lie within the nozzles *h*, and which are contracted at their mouths, leaving a narrow orifice through which the steam may issue in a very powerful jet. N is a pipe leading from the steam-room of the boiler into the hollow ring, M, and admitting the steam therein under the control of the cock, *n*. Whenever this cock is opened, steam from the boiler fills the internal ring, M, at nearly the full boiler pressure, and the live steam, in rushing from the nozzles, *m*, drags inward great volumes of fresh air. This apparatus for admitting steam and air to mingle with the hot gases, may be employed with some advantage in many conditions of work; but one of its most important uses is to insure complete combustion of the smoke when the locomotive is standing at the station. On approaching the station, and shutting off the steam from the engines, the engineer opens the cock, *n*, either partially or entirely, the slide, I, being supposed

to be opened nearly all of the time, to admit air into the ring, H. The opening of the cock, *n*, allows the steam from the boiler to fill the internal pipe, M, and to commence to blow through the nozzles, *m*. The waste of steam is almost unappreciable, even if the cock, *n*, be wide open; but in most cases it is sufficient to open this cock to a small extent, and the air drawn in through the pipes, H1 H1, and thrown into the fire through the nozzles, *h*, mingles with the hot, combustible gases, and effects their complete combustion in the upper chamber, B, of the fire-box. The gases are turned out from the chimney in a condition very nearly transparent, and the inconvenience is very greatly lessened. The placing of the hollow ring, H, and its contents above the inclined partition, B1 C1, and so as to surround the hole, D, as represented, protects the hollow ring from the intense radiant heat of the fire, and insures that the fresh air shall be thrown into the hot gases at such a point that they shall find sufficient heat to ignite them, with sufficient space above to allow time for the perfect combustion of the gases. The construction of our inclined partition allows a very active current of water, or water mingled with steam, to flow constantly from the lower edge to the higher. The water is drawn in freely from the water-leg on the front side of the lower portion of the fire-box, and becoming heated and partially changed into steam by the intense heat applied on the lower face, C1, of the inclined diaphragm, it divides and passes around the flanges, *b c*, finding ample space each side, and between them if there are two, to rush actively upward and emerge at the upper edge, and rise in a strong current and discharge the steam into the steam space in the boiler. This action goes on uninterrmittently and with great freedom. Where there are two or more of the holes, D, it will of course be understood that there are a correspondingly increased number of the flanges, *b c*, rivets, F, and hollow rings, H, and their connections. Our hollow rings, H, and their connections provided with the strong steam jets issuing from the nozzles, *m*, as described, form a very cheap and effective means of introducing fresh air under a considerable pressure in the upper part of the furnace. The effect is superior in several important respects to the introduction of air without pressure at this point, or to the introduction of air under pressure below the grate. Air, without pressure, will not enter in sufficient volumes to complete the combustion of the immense volumes of combustible gases and smoke. The air introduced by our means in the upper portion of the furnace enters with great force in sufficient volumes to complete the combustion, and by its forcible entering at these points does not in the least increase, but rather diminishes the intensity of the upward draught through the incandescent fuel below. We propose to incline the nozzles, *m* and *h*, upward to a slight extent, as shall be found expedient, in order to induce the proper effect on the draught of the fire while the locomotive is standing still. If, in any case, it be found desirable to greatly retard the draught, we can incline one or more of the jets issuing from the nozzles, *m h*, slightly or directly downward. But we do not believe it necessary to incline them very greatly either upward or downward. We propose usually to project them inward with an upward inclination of about ten degrees, as represented. A1 A2

is an inclined joint in the shell directly opposite to the inclined partition, B1 C1, and extending from the front to the back of the fire-box on each side of the boiler.

Some of the advantages due to certain features of our invention may be separately enumerated as follows:

1. By reason of the division of the fire-box, B C, into an upper and lower chamber, as represented, we are able to burn the gases with facility, to protect the metal of the upper portion from the violent heating and cooling to which the lower part is exposed, and to better allow of the additional features of our invention by which air is introduced at the right point; the apparatus, therefore, is protected, and the lower portion is renewed without disturbing the upper portion.

2. By reason of the fact that the flanges, *b c*, and rivets, F, are arranged as represented relatively to the inclined partition, B^1 C^1, and to the other parts, we are able to provide a strong and reliable connection of the parts, and to allow a very easy separation when desired.

3. By reason of the fact that the hollow ring, H, adapted to supply steam and air, as described, is arranged as represented relatively to the inclined partition, B^1 C^1, and to the aperture, D, therein, we are able to introduce the air under pressure in the upper part of the fire-box, and to graduate its influx at will by apertures well protected from the radiant heat of the fire, and to insure an efficiency in the introduction of the air and the mixing thereof with the flame at the proper period, which has not been heretofore attainable with equally simple apparatus.

4. By reason of the fact that the steam-pipe, M, with its nozzles, *m*, is arranged as represented relatively to the air-pipes, H^1 H^1, and the steam-pipe, N, and to the nozzles, *h*, we are able to protect the steam apparatus from destructive influences, and to preserve it in condition for supporting a powerful steam pressure even after it has been many times and for long periods in position with the steam shut off.

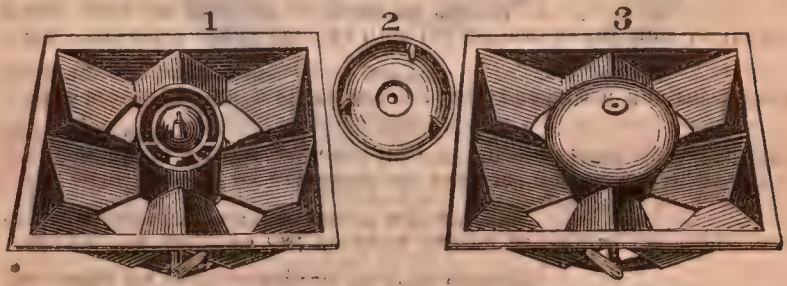
5. By reason of the fact that the slanting seam, A^1 A^2, of the external fire-box, is arranged opposite to the inclined partition, B^1 C^1, and has a corresponding inclination, we are able by

cutting these lines of rivets alone to disconnect the sheets, and to more conveniently remove and renew the lower portion of the outer fire-box as well as the inner.

Recent trials of this patent fire-box, without the air and steam tubes in the fire-box, having merely the openings for the admission of air through the back of the fire-box, give most satisfactory results—equal, in all respects, to the method as first specified.

COAL-BURNING ASH-PAN.

A device, patented in 1867 by Messrs. Lansing & Chase, to produce a uniform draft through the grate-bars of a locomotive, capable of regulating and checking the admission of air at pleasure, and a safeguard from fire, in preventing escape of coals from the ash-pan. As shown in the cut, the air is admitted through the centre opening in bottom of pan; in passing upwards it meets the cone damper, and is deflected evenly over the surface of the bars, being heated by contact with the grate before entering the fire. By lowering the cone damper, the admission of air is entirely cut off. To cleanse from ashes, the bottom of the pan is moveable on a centre, allowing openings in the bottom, to be opened or closed by turning a lever.



The advantages claimed are—

1st—For *entire protection and safety from fire* by its prevention of scattering live coals upon the track, as it is impossible for fire to escape from it.

2d—For *its great economy in fuel.* In a recent trial of twelve days by first-class engines, and carefully made, its *average saving* over the old arrangement was for soft coal 23 29-100 *per cent*, and for hard coal 33 31-100 *per cent*. The heating of the air before it reaches the fire, and the perfection in consuming the gases, constitute its great economy.

3d—For its *simplicity and durability*, lasting as long as the engine, and can be attached without the loss of a single trip.

4th.—The *control of the quantity of air* admitted to the fire is always at the command of the engineer, and the *retention of the steam* for a long time thereby secured.

5th.—Less depreciation of the fire-box sheets and back-flue sheets by a more uniform temperature in the fire-box.

6th.—The ashes can be emptied from the ash-pan at any time by the engineer using the lever always under his control.

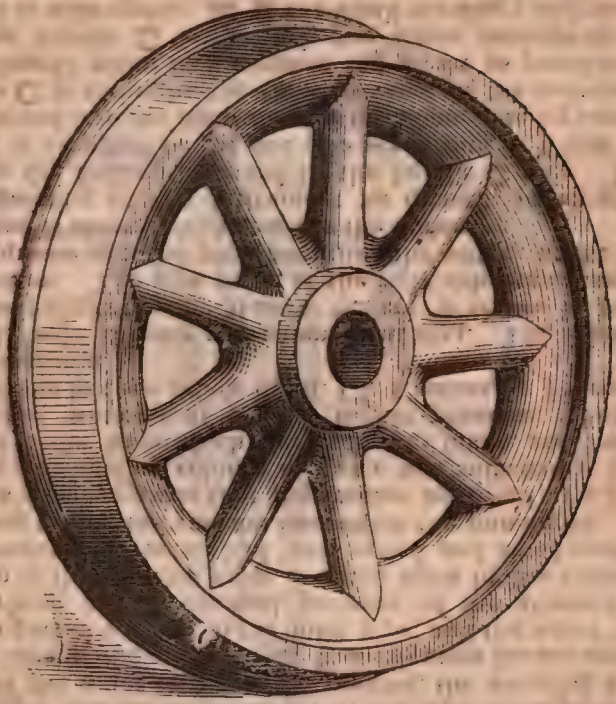
The *saving of fuel* upon the basis of trials made by the Erie Railway Company amounts to about *one thousand dollars* per annum for each engine, as per following tables:

Engine No. 205, Soft Coal.	Miles Run.	Pounds of Coal Burned.	Average Lbs. per Mile.	Miles Run pr. Ton.	Cars Drawn.	Saving.
Old Ash-pan.	540	35,150	$65\frac{6}{100}$	$34\frac{40}{100}$	90	
New Ash-pan	620	30,960	$49\frac{93}{100}$	$44\frac{86}{100}$	86	$23\frac{29}{100}$ pr ct.

Engine No. 341, Hard Coal.	Miles Run.	Pounds of Coal Burned.	Average Lbs. per Mile.	Miles Run pr. Ton.	Cars Drawn.	Saving
Old Ash-pan.	465	45,120	$97\frac{3}{100}$	$23\frac{8}{100}$	120	
New Ash-pan	465	30,090	$64\frac{71}{100}$	$34\frac{62}{100}$	123	$33\frac{31}{100}$ pr. ct.

VIEW OF

HOLLOW SPOKE AND RIM



ENGINE AND TENDER TRUCK WHEELS,

AS MADE BY

THE RAMAPO WHEEL AND FOUNDRY CO.

Ramapo Wheel and Foundry Co.

GIFFARD'S INJECTOR.

The action of the injector is that which Venturi, in the beginning of the present century, designated as the "lateral action of fluids," and having been investigated by Dr. Young in 1805, was proposed by Nicholson in 1806, for forcing water. The action is identical to that of the steam jet in locomotive boilers. The principle is, steam being admitted to the inner tube of the injector, and the central conical valve being withdrawn, the steam escapes in a jet near the top of the inlet water pipe. If the level of the water be below the injector, the escaping jet of steam, by its superficial action (or friction) upon the air around it, forms a partial vacuum in the inlet pipe, and the water then rises in virtue of the external pressure of the atmosphere. Once risen to the jet, the water is acted upon by the steam in the same manner as the air had been seized and acted upon in first forming the partial vacuum into which the water rose.

Giffard's discovery was that the motion imparted by a jet of steam to a surrounding column of water was sufficient to force it into the boiler from which the steam was taken, and indeed into a boiler working at even a higher pressure. For an analysis of this fact see article by M. Ch. Combes, in Journal of Franklin Institute.

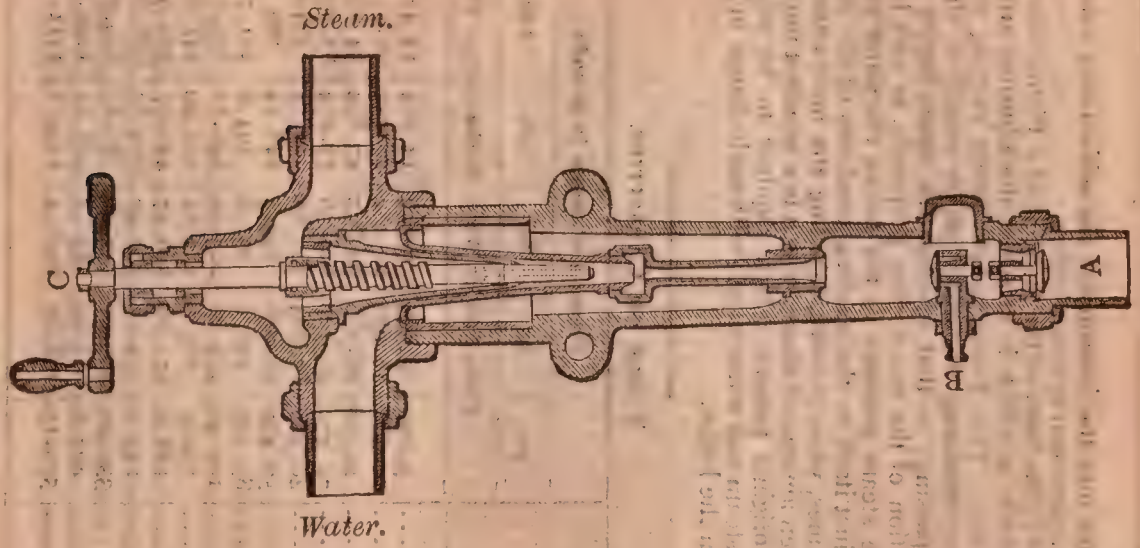
H. J. Giffard's Injector was patented in 1854. The injector, as made self-regulating by Messrs. Sellers, is shown in longitudinal section. The pipe rising at the right side admitting the steam; opposite to it the pipe admitting the water; at the bottom the pipe is shown which leads to the boiler.

The regulating of this instrument for quantity of water injected into the boiler is effected by the handle **C** only. This handle **C** is attached to the end of a screw plug. When this plug is screwed into the instrument as far as possible, by turning the handle **C** to the right, the steam passage in the instrument is nearly closed; when it is screwed out as far as possible, by turning the handle **C** to the left, the steam passage in the instrument is wide open. At **B** is a small opening; and within the instrument, at this point, is a valve called the "self-starting valve." There is also at the end of the instrument, at **A**, a check valve. These valves are so arranged that when the check valve at **A** is closed to prevent the water in the boiler

GIFFARD'S INJECTOR,

AS MADE SELF-ADJUSTING BY WM. SELLERS & CO.,

OF PHILADELPHIA.



MESSRS. SELLERS & CO., on application, will furnish full particulars, with price list and cuts, of their injectors.

Ramyo Wheel and Foundry Co.

flowing back into the instrument, the self-starting valve is open when the instrument ceases working.

There is in the body of the instrument a Piston moving freely back and forth, to which is attached the adjusting arrangement for the water. This Piston moves under varying pressure of steam, accommodating the water supply exactly to the amount of steam passing; so that whether the steam supply be varied by the motion of the steam plug purposely, or vary by fluctuation of the steam pressure in the boiler, the water supply will always adjust itself to the existing condition of the steam, and be at all times, when at work, injecting the most water possible with a given amount of steam, which is a manifest improvement over the original pattern, which required to be adjusted by hand, for steam and water supply with each change in the steam pressure in the boiler.

TABLE OF CAPACITIES.

SIZE.	Pressure of Steam in pounds.					
	10	30	60	90	120	150
	Cubic Feet of Water discharged per hour.					
No. 2.....	5.050	7.344	9.824	11.794	13.479	14.941
No. 3.....	11.465	16.658	22.284	26.752	30.574	33.89
No. 4.....	20.50	29.786	39.845	47.834	54 667	60.596
No. 5.....	32.175	46.748	62.536	75.074	85.799	95.106
No. 6.....	46.500	67.564	90.381	108.5	124.0	137.45
No. 7	50.431	92.246	123.4	148.14	169 3	187.67
No. 8.....	83.145	120 8	161.6	194.0	221.72	245.77
No. 9.....	105.48	153.26	205.01	246.12	281.28	312.05
No. 10.....	130.5	189.6	253.64	304.49	347.99	385.73
No. 12.....	188.6	274.03	366.57	440.07	502.93	557.49
No. 14.....	257.5	374.13	500.49	600.83	686.66	761.14
No. 16.....	337.22	489.97	655.44	786.85	899.26	996.8
No. 18.....	427.8	621.59	831.5	998.21	1140.8	1264.6
No. 20.....	529.15	768.83	1028.1	1234.7	1411.1	1564.1

One nominal horse-power per hour will require one cubic foot of water per hour. When the pounds of coal consumed per hour can be ascertained, divide this by 7.5, and the remainder will be the quantity of water in cubic feet per hour.

Minimum capacity of injectors about 40 per centum of tabular capacity.

Maximum temperature of feed admissible at different pressures of steam;

Pressure of steam lbs. per sq. in.	10	20	30	40	50	100
Temperature of feed, Fahr.....	148°	138°	130°	124°	120°	110°

COMBUSTION.

Carbon is in a pure state in charcoal and soot; it combines with no more than 2⅔ of its weight of oxygen. In its combustion, 1 pound of it produces sufficient heat to increase the temperature of 13,000 pounds of water 1 degree.

Hydrogen exists in a gaseous state, and combines with 8 times its weight of oxygen, and 1 pound burning raises the heat of 42,000 pounds of water 1 degree.

Air consists of oxygen and nitrogen, mixed in proportion of 1 pound of oxygen to 3.29 pounds of nitrogen.

Every pound of coal requires 2.66 pounds of oxygen for its saturation; therefore, for every pound of coal burned, 8.75 pounds nitrogen must pass through the fire. In practice ⅓ oxygen will pass through the fire without combining with it, so that 16 to 18 pounds of air are required for every pound of coal burned. 18 pounds of air equals 240 cubic feet, which is the amount of air in practice required for the combustion of a pound of coal

Bituminous coal equals 80 to 90 per cent. carbon, 8 to 18 per cent. of volatile matter, viz., hydrogen, nitrogen, oxygen, and sulphur.

Anthracite coal equals 91 per cent. carbon, 7 per cent. volatile matter, 2 per cent. ashes.

Bulk of products of combustion in a furnace equals 465 feet for each pound bituminous coal burned.

Evaporative Powers of Fuel.

1 pound of coal evaporates 9 pounds of water.
1 pound of coke evaporates 9 pounds of water.
1 pound of wood evaporates 4½ pounds of water.
1 pound of turf (peat) evaporates 6 pounds of water.
Stationary engines use 3 to 7 pounds coal per horse-power per hour.
Locomotive passenger engines, 25 to 30 pounds coal per mile.
Locomotive freight engines, 45 to 55 pounds coal per mile.
Wood-burning locomotives, 1 cord of wood to 24 miles.
Bulk of wood about 6 times as much as an equivalent of coal.

Charcoal.

Wood will furnish 16 per cent. of coal.
A bushel of hard-wood coal equal to 30 pounds.
A bushel of pine-wood coal equal to 29 pounds.

Coke.

60 bushels, 2,150.42 cubic inches, Newcastle coal, will make 92 bushels good coke.
60 bushels fine coal, equal 85 bushels coke.
60 bushels Virginia coal, equal 75 bushels coke.
1 bushel coke weighs 32 pounds.
Production of coke, by weight, equals ⅔ of that of coal.
Coal furnishes 60 to 70 per cent. of coke by weight.
1 pound Anthracite coal will melt 5 to 8 pounds of cast iron.
80 bushels of bituminous coal will melt 10 tons of cast iron in an air furnace.

Wood.

1 cord of yellow pine = 2,700 lbs., or 106.6 cubic feet, to stow 1 ton (Virginia). Southern = 3,300 lbs.
2¼ to 2¾ pounds of wood equal to 1 pound of coal.
1 cord of Western wood equals 12 bushels, or 960 pounds, Pittsburg coal.

Average Weight per Bushel of Coals.

1 bushel	Anthracite =	86 lbs.
1 "	Bituminous =	80 "
1 "	Charcoal (hard-wood) =	30 "
1 "	Coke =	32 "

Weight and Value for Fuel of Cord Wood.

Name of Wood.	Weight per Cord.	Value as Fuel.
Shell-bark hickory	4,469 lbs.	100.
Red-heart hickory	3,705 "	81.
White oak	3,821 "	81.
Red oak	3,254 "	69.
Hard maple	2,878 "	60.
Jersey pine	2,137 "	54.
Yellow pine, N	1,904 "	43.
White pine	1,868 "	42.

Heating Powers of Peat,
As compared with Wood.

100 lbs. turfy peat, air dry, average	95 lbs.	pine wood.
100 lbs. fibrous " " "	108 "	"
100 lbs. earthy " " "	104 "	"
100 lbs. pitchy " " "	111 "	"

Comparison of Heat by Bulk.

100 cubic feet of turfy peat	= 33	cubic feet	pine wood	in logs.
100 " fibrous "	= 90	"	"	"
100 " earthy "	= 145	"	"	"
100 " pitchy "	= 184	"	"	"

Peat, coal, or coke = 25 to 35 of the peat by weight.
" " " = 30 to 40 per cent. by volume.

Properties of Fuel.

Kind of Fuel.	Lbs. of Water evaporated per pound.	Per cent. of carbon.	Cubic feet of air required for 1 lb. of coal.	Weight per cubic foot.	Cubic feet to stow 1 ton.
Bituminous Coal.....	7 to 9	80	265	50	44
Anthracite.....	8 to 10	92	282	54	40
Coke.....	8 to 10	86	245	31	72
Coke, Nat'l Virginia..	8 to 9	80	260	48	48
Coke, Cumberland.....	8 to 10	80	250	32	70
Charcoal.....	5 to 6	96	265	24	104
Dry Wood.....	4 to 5	44	147	20	100
Wood, 20 per ct. water.	4	34	115	25	100
Turf, dry (peat).....	6	51	165	28	80
Turf, 20 per ct. water..	5	40	132	30	75
Illuminating gas.....	13.8	..	194	0.37	29800
Oil, wax, tallow.....	14	77	200	59	37
Alcohol.....	9.56	58	154	52	42

Chimneys.

To find dimensions of chimney of a land engine. Multiply number of pounds of coal consumed under the boiler per hour by 12; divide the product by square root of the height of chimney in feet. Quotient is area of chimney at smallest point in square inches.

Draught or Velocity of Air in Chimneys.

In feet per second.

H = Height of shaft or of heated column of air in feet.
T = Temperature of room or flue in deg. Fahr.
t = Temperature of external air.

$$\text{Velocity} = .365 \sqrt{H(T-t)}.$$

The retardation of air by friction in passing through straight tubes will be directly as the length and square of the velocity, and inversely as the diameter.

Areas of American Coal-fields.

Massachusetts and Rhode Island, Anthracite.	300	sq. miles.
Pennsylvania, Anthracite	470	"
Pennsylvania, Bituminous	12,656	"
Maryland, "	550	"
West Virginia, "	15,000	"
East Virginia, "	225	"
North Carolina, "	45	"
Tennessee, "	3,700	"
Georgia, "	170	"
Alabama, "	4,300	"
Kentucky, "	13,700	"
Ohio, "	7,100	"
Indiana, "	6,700	"
Illinois, "	30,000	"
Michigan, "	13,000	"
Iowa, "	24,000	"
Missouri, "	21,000	"
Nebraska, "	4,000	"
Kansas, "	12,000	"
Arkansas, "	12,000	"
Indian Territory, "	10,000	"
Texas, "	3,000	"
Oregon, "	500	"
Oregon, Anthracite	100	"
Washington Territory, estimated, Bituminous.	750	"
West of Rocky Mountains	5,000	"
	200,266	"
To which may be added, as recent formations, Tertiary coals, Lignites, etc., mostly near the Rocky Mountains	200,000	"

Workable Coal Formations of Various Countries.

British North American Provinces.

Cape Breton, Sidney coal	200	sq. miles.
Newfoundland	259	"
Pictou	350	"
Cumberland	250	"
Prince Edward's Island	150	"
New Brunswick	1,000	"
Total	2,200	"

Area of the European Coal-fields.

Great Britain	6,195	sq. miles.
France	1,000	"
Belgium	510	"
Saarbrook coal-field	960	"
Westphalia	380	"
Bohemia	400	"
Saxony	30	"
Spain	200	"
Russia	100	"
Total sq. miles workable coal area	9,775	"

Proportion of coal in Europe, 1 sq. mile to every 375 of territory.
" " " England, 1 " " 20 "
" " " U. States, 1 " " 15 "

The whole of Europe, comprising a total area of 3,785,000 square miles, has less than 10,000 square miles of coal producing area.

The islands of Great Britain, with total area of 121,000 square miles, contains more than half the coal-producing area of Europe.

The United States, with 3,250,000 square miles, has over 200,000 square miles of coal-producing area.

Coal Fields of the World, and their Productions.

	Area of Coal Fields in square miles.	Productions in 1864.
		Tons.
British Islands	6,195	86,000,000
United States	200,000	22,000,000
Prussia and Saxony	1,000	12,000,000
France	1,000	10,000,000
Belgium	510	10,000,000
Austria and Bohemia	1,000	2,500,000
Spain	200	400,000
British America	2,200	500,000
Total coal production of the world	.....	143,400,000

Production of Coal in the United States in 1865.

Bituminous	11,324,207 tons.
Anthracite	11,532,732 "
Total United States	22,856,939 "

Memoranda concerning Coal and Iron.

First notice found of stone coal is B. C. 371.
The coal fields of England were the first practically developed.
First record of stone coal used in England was A. D. 820.
Records of regular mining in England first made in 1180.
Coal first used in London in 1240.
First tax laid on coal in England in 1379.

Tax was repealed in 1831, having been taxed 400 years.

First patent for making iron with pit coal was granted to Simeon Sturtevant in 1612, but was not successful.

Iron first made in a blast furnace with pit coal with success by a Mr. Darby, of Colebrook Dale, England, in 1713.

In 1747 iron was made in England with pit coal, suitable for the manufacture of cannon.

In 1788 the production of iron with pit coal in England was 48,300 tons; with charcoal, 13,000 tons.

In 1864 the production of iron in Great Britain was 5,000,000 tons.

Wooden rails in mines were used in 1777.

Cast-iron rails in mines were used in 1790.

Wrought-iron rails in mines were used in 1815.

Coal gas first made use of practically in 1798.

American Coal Fields.

First coal fields worked in America were the bituminous fields at Richmond, Va., discovered in 1750. This coal was used at Westham, on the James River, to make shot and shell during the War of Independence.

The first use of Anthracite coal was in 1768–69.

First used for smithing purposes in 1790.

First used to burn in a common grate in 1808.

First successful use of Anthracite coal for the smelting of iron was in 1839, at the Pioneer Furnace, at Pottsville, Pa. It had been tried on the Lehigh in 1826, but was unsuccessful.

The total productions of pig iron in the United States, in 1864, of—

Anthracite iron	684,319	tons.
Bituminous and Coke iron	210,108	"
Charcoal iron	255,486	"
Charcoal iron (Southern States)	50,000	"
	1,199,913	"

HEAT.

Table showing the increased Volume which any given quantity of Air at 32° will acquire, by raising its Temperature through a given number of degrees.

TEMPERATURES OF COMBUSTION AND VOLUMES OF PRODUCTS.

Temperatures.	Supply of Air, in pounds, per pound of Fuel.		
	12 lbs.	18 lbs.	24 lbs.
	Volume of Air or Gases, in cubic feet, at each Temperature.		
32°	150	225	300
68	161	241	322
104	172	258	344
212	205	307	409
392	259	389	519
572	314	471	628
752	369	553	738
1,112	479	718	957
1,472	588	882	1,176
1,832	697	1,046	1,395
2,500	906	1,359	1,812
3,275	1,136	1,704	....
4,640	1,551	....	....

EXPANSION OF WATER BY HEAT. (*Dalton.*)

Temp.	Expan.	Temp.	Expan.	Temp.	Expan.
12°	1.00236	82	1.00312	152°	1.01934
22	1.00090	92	1.00477	162	1.02245
32	1.00022	102	1.00672	172	1.02575
40	1	112	1.00880	182	1.02916
52	1.00021	122	1.01116	192	1.03265
62	1.00083	132	1.01367	202	1.03634
72	1.00180	142	1.01638	212	1.0402

EXPANSION OF SOLIDS. (*Faraday.*)

Lineal at 212°, the Length of the Bar at 32° = 1.

Bismuth	1.0013908	Gold	1.001495	Silver	1.00201
Brass	1.0019062	Granite	1.0007894	Slate	1.0011436
Cast-iron	1.0011112	Lead	1.0028426	Stock brick	1.0005562
Cement	1.001435	Marble	1.0011041	Steel	1.0011899
Copper	1.001745	Pavements	1.0008985	Tin	1.002
Fire brick	1.0004928	Platinum	1.0009542	W. iron	1.0012575
Glass	1.0008545	Sandstone	1.001743	Zinc	1.002942

For Expansion of Air, see page

STEAM.

The vapor arising from water, at its boiling point, called steam—is a chemical compound—8 parts, by weight, of oxygen to 1 of hydrogen. Steam proper is perfectly transparent and colorless, dry, and only moist when condensed; wholly invisible, and when apparent, only so by reason of partial condensation.

Its density is equal to pressure of the atmosphere, or 14.72 lbs. per square inch, and, unless confined, the temperature of water cannot be raised above the boiling-point. The addition of 1 degree in the temperature of steam, will increase its volume 0.00202 of the volume occupied by the fluid at 32°.

One cubic inch of water evaporated, under ordinary pressure of atmosphere, is converted into 1,700 cubic inches of steam, or nearly 1 cubic foot; it exerts a mechanical force equal to raising 2120.14 lbs. 1 foot high.

One cubic foot of steam, evaporated in one hour, is equal to 1 horse-power.

27.222 cubic inches of steam, at atmospheric pressure equal 1 lb. avoirdupois; 1 lb. of water, heated from 32° to 212°, requires as much heat as would raise 180 lbs. 1°.

1 lb. of water, at 212°, converted into steam at 212° (pressure of 14.72 lbs.), absorbs as much heat for its conversion as will raise 966.6 lbs. of water 1°.

Pressure of 1 lb. per square inch will support a column of mercury (60° F.) 2.0376 inches; therefore in a syphon gauge (U), one half of this, or 1.0188 inches.

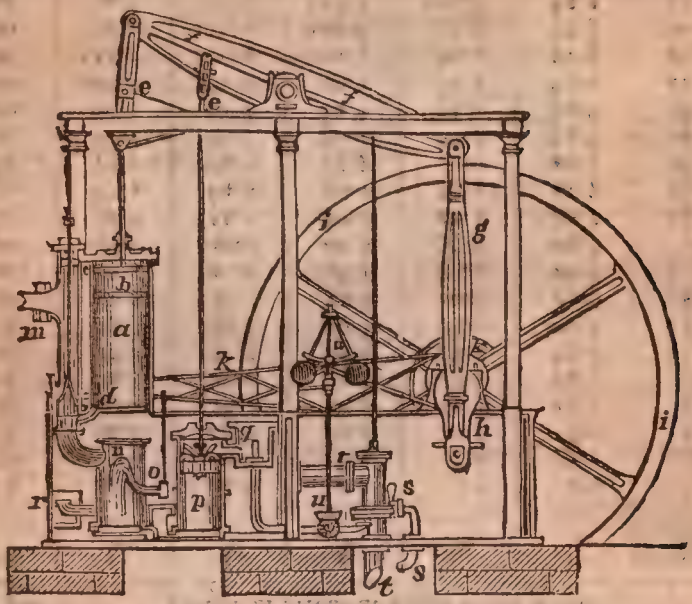
1 lb. of steam will raise 3.657 cubic feet of air 10°, *i. e.* from 32° to 40°, and cause it to expand 3.733 cubic feet.

The heat which will raise 1 lb. of water 1°, will raise 1 lb. of air 3°.7. 1 lb. of air = 11 cubic feet.

Steam of atmospheric pressure flows into a vacuum at rate of 1,550 feet per second; at 10 atmospheres, or 147 lbs. pressure, flows into a vacuum at 1,780 feet per second; at 10 atmospheres, flows into the air at 650 feet per second; at 20 atmospheres, or 294 lbs. pressure, at 1,600 feet per second.

Diagram of a Condensing Steam-Engine,

With Letters of Reference to the Names of the Various Parts.



a, steam cylinder; *b*, piston; *c*, upper steam port or passage; *d*, lower steam port; *e*, *e*, parallel motion; *f*, *f*, beam; *g*, connecting rod; *h*, crank; *i*, *i*, fly-wheel; *k*, *k*, eccentric and its rod for working the steam-valve; *l*, steam-valve and casing; *m*, throttle-valve; *n*, condenser; *o*, injection-cock; *p*, air-pump; *q*, hot well; *r*, shifting-valve to create vacuum in condenser previous to starting the engine; *s*, feed-pump to supply boilers; *t*, cold-water pump to supply condenser; *u*, governor.

Table of Steam used Expansively,

Giving the average pressure throughout the stroke at any of the points of cut off and commencing pressures named.

Initial Pressure lbs per square inch.	Average Pressure of Steam in lbs. per square inch for the whole stroke.					
	Portion of Stroke at which Steam is Cut off.					
	¾	⅝	½	⅜	¼	⅛
5	4.8	4.6	4.2	3.7	2.9	1.9
10	9.6	9.1	8.4	7.4	5.9	3.8
15	14.4	13.7	12.7	11.1	8.9	5.7
20	19.2	18.3	16.9	14.8	11.9	7.6
25	24.1	22.9	21.1	18.5	14.9	9.5
30	28.9	27.5	25.4	22.2	17.9	11.5
35	33.8	32.1	29.6	25.9	20.8	13.4
40	38.5	36.7	33.8	29.6	23.8	15.4
45	43.4	41.3	38.1	33.3	26.8	17.3
50	48.2	45.9	42.3	37.0	29.8	19.2
60	57.8	55.1	50.7	44.5	35.7	23.1
70	67.4	64.3	59.2	52.4	41.7	26.9
80	77.1	73.5	67.7	59.3	47.7	30.8
90	86.7	82.6	76.1	66.7	53.6	34.6
100	96.3	91.8	84.6	74.1	59.6	38.4
110	106.0	101.0	93.1	81.5	65.6	42.5
120	115.2	110.2	101.5	89.4	71.5	46.1
130	125.4	119.1	110.0	95.3	77.5	50.0
140	134.9	128.6	118.5	103.8	83.3	53.8
150	144.7	137.8	126.3	111.2	89.4	57.7
160	153.6	147.0	135.4	118.2	95.4	61.5
180	173.5	164.6	152.3	132.9	107.3	69.2
200	192.7	183.7	169.3	148.3	119.3	76.9

Table of the Elastic Force of Steam.

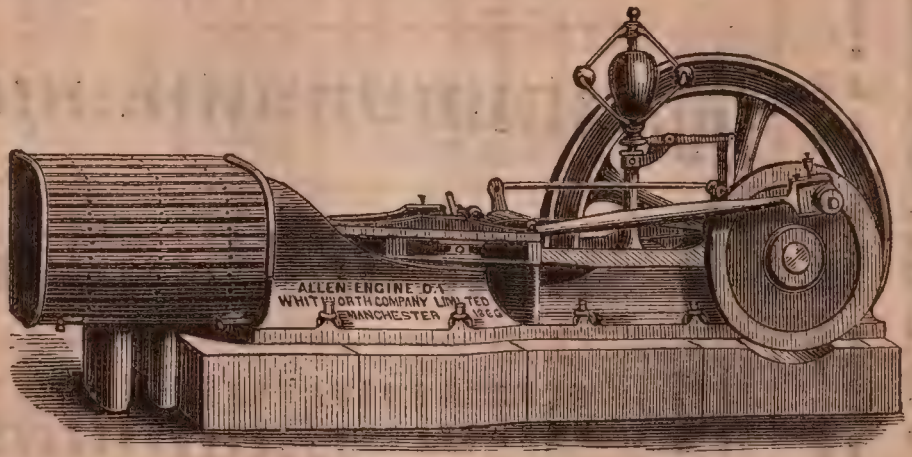
Temperature and Volume of Steam made by a cubic foot of Water under different pressures.

Pressure on a square inch, including atmosphere.	Elastic Force, in inches, of Mercury.	Temperature of Steam.	Volume of Steam compared with volume of Water.	Density.
1	2.03	102.1	20582.	.0000477
5	10.07	162.3	4527.	.000225
10	20.35	193 3	2358.	.000426
15	30.53	213.1	1610.	.000599
20	40.71	228.0	1229.	.00078
25	50.88	240.1	996.	.000957
30	61.06	250.4	838.	.001132
35	71.24	259.3	726.	.001304
40	81.42	267.3	640.	.001472
45	91.59	274.4	572.	.001639
50	101.77	281.0	518.	.001805
60	122.13	292.7	437.	.002127
70	142.48	302.9	378.	.002451
80	162.84	312.0	333.	.002762
90	183.19	320 2	298.	.003076
100	203.55	327.9	270.	.003389
110	223.90	334.6	247.	.00369
120	244.26	341.1	227.	.003984
130	264.61	347.2	211.	.004291
140	284.97	352.9	197.	.004587
150	305.32	358.3	184.	.004879
160	325.68	363.4	174.	.005181
170	346.03	368.2	164.	.005464
180	366.39	372.9	155.	.005747
190	386.74	377.5	148.	
200	407.10	381.7	141.	

ALLEN ENGINE,

With Self-Regulating Valve Motion,

As manufactured by the Whitworth Company, Manchester, England.



This engine derives its importance from its great saving of fuel, uniformity of motion, and speed at which it can be driven, combined with lightness of parts, and economy in first cost. For circulars and particulars, address

JOHN F. ALLEN, *Tremont, N. Y.*

Richmond Iron.

ACTUAL HORSE-POWER.

One actual horse-power equals 33,000 pounds, raised one 100t high in one minute. Applied to steam engines will be mean steam pressure on cylinder piston in pounds, multiplied by the velocity of piston in feet per minute, divided by 33,000; from this deduct 25 per cent. in condensing engines and 13.1 per cent. in high-pressure engines, for working friction and pumps; balance to be termed actual horse-power.

To find Actual Horse-Power of a Condensing Engine.

Area of steam cylinder, multiplied by stroke of piston in feet, multiplied by average pressure of steam per square inch of piston, multiplied by number of revolutions per minute; the sum divided by 22,000 will give actual horse-power.

To find Actual Horse-Power of High-Pressure Engine.

Proceed as for condensing engine, except divide by 19,000 in place of 22,000.

Examples—To find horse-power of condensing engine, cylinder 48 ins. diameter; 4 feet stroke of piston; indicated pressure of steam, 30 lbs.; expanded, ⅔; engine making 45 revolutions per minute. First, to the pressure of steam, 30 lbs., add atmospheric pressure of 15 lbs., making 45 lbs., expanded ⅔, gives a mean pressure of 31.45 lbs.; to which add pressure of the vacuum, 12 lbs., which gives 43.45 lbs.; deduct 14.7 lbs. atmospheric pressure, giving mean pressure on piston 28.75 lbs.; then area of 48 ins.

$$= \frac{1809 \times 4 \times 28.75 \times 45}{22,000} = 425.6 \text{ horse-power.}$$

Example—To find actual horse-power of high-pressure engine. Cylinder 16 in. diameter, 3 feet stroke; steam-pressure, 80 lbs. per square inch; expanded ½; engine making 56 revolutions per minute. Required actual horse-power.

To find mean pressure: To the given pressure add atmospheric pressure of 15 lbs. = 80 + 15 = 95; expanded ½; from

expansion table = 80.412 lbs.; from which deduct atmospheric pressure of 14.7 lbs. = 65.712 lbs.

$$\text{Area of } 16 = \frac{201 \times 3 \times 65.712 \times 56}{19{,}000} = 116.7 \text{ horse power;}$$

or, for *Condensing Engines*, $\dfrac{A \times \overline{P - f} \times 2\,s\,r}{33{,}000} = \text{H. P.}$

A = area of cylinder, in square inches; P, mean effective pressure upon piston, in lbs., per square inch, inclusive of atmosphere; f, friction of the engine, added to the friction of the load, in lbs., per square inch; s, stroke of piston, in feet; and r, number of revolutions per minute.

For *High-Pressure Engines*,

$$\frac{A \times \overline{P - (f + 14.7)} \times 2\,s\,r}{33{,}000} = \text{H. P.}$$

Nominal Horse-Power.

Condensing Engine.—Diameter of cylinder, in inches, squared, multiplied by velocity of piston, in feet, per minute; product divided by 3,000 = H. P.

N. B.—This is based on a uniform steam pressure, taken at 10 lbs. per square inch, on steam gauge; cutting off at half stroke, deducting one-fifth for loss of friction; mean velocity of piston = 250 feet per minute for long stroke engines, 200 feet per minute for short strokes.

High-Pressure Engines.—Proceed as above, only divide by 1,000 in place of 3,000.

N. B.—This is based on a uniform steam pressure of 60 lbs. per square inch on steam-gauge; cut off at half stroke, deducting one-sixth for losses and friction; mean velocity of piston = 250 feet per minute.

Friction and losses of a marine engine may be taken at 1.5 to 2 lbs. per square inch for friction of load in all its parts, and the friction of the load may be taken at 5 to 7½ per cent. of the remaining pressure.

Power to work the air-pump = 0.7 to 0.9 lbs. per square inch upon cylinder piston.

When an indicator is not used, pressure of steam on piston may be taken at from 0.75 to 0.8 of the boiler pressure, when acting at full stroke; when acting expansively, at 0.9 of the full pressure.

To find Volume of Water required to be Evaporated in a Steam-Engine.

Multiply volume of steam expended in cylinder and steam-chests by twice the number of revolutions; product multiplied by density of steam (page 255) at pressure given = volume of water.

Maximum Volume of Water required to Condense Steam.

For fresh water = 35 times volume of water evaporated; in Gulf of Mexico = 70 times the volume of water evaporated.

To Compute Consumption of Fuel in a Steam-Engine.

Rule—Compute volume of cylinder to point of cutting off steam; multiply result by number of cylinders, by twice the number of revolutions of engine, and by 60 (minutes), and divide the product by density of the steam at its pressure in the cylinder; quotient will give number of cubic feet of water expended in steam; multiply the number of cubic feet by 64.3125, divide the product by the evaporation of the boiler per lb. of fuel consumed, and quotient will give consumption in pounds per hour.

Ratio of Combustion.

Fuel burned per hour per square feet of grate, varies per different kinds of boilers: Cornish = 3½ lbs. per square foot; land boilers = 10 to 20 lbs.; (English), 13 to 14 lbs.; marine boilers (natural draught), 10 to 18 lbs.; (blast), 30 to 60 lbs.; locomotive boilers, 80 to 120 lbs.

Anthracite coal will evaporate 7½ to 9½ lbs. of water per pound of coal; bituminous coal, 6 to 10 lbs. of water; coke, 7½ to 8½ lbs.; wood, 4½ lbs.

Duty of Steam-Engines.

Conventional duty = number of pounds raised by it 1 foot high by a bushel of bituminous coal (112 lbs.)

Cornish Engine.—Average duty = 70,000,000 lbs.

Condensing Marine Engine.—Steam, 15 lbs. (mercurial gauge), cut off at half stroke, requires 2.07 lbs. bituminous coal per actual horse-power. Evaporation = 10.5 lbs. water per pound of Welsh coal consumed.

Portable Engine.—Cylinder, 6¼ inches diameter; stroke, 4 feet; 115 revolutions; steam cut off at half stroke—requires 17.28 lbs anthracite coal per hour.

Relative Cost of Engines for Equal Duties

In Pounds of Coal per Horse-Power per Hour.

A theoretically perfect steam-engine	0.66 lbs.
A Cornish condensing engine	2.38 "
Ericsson's air engine	3.86 "
A marine condensing engine	2 to 6 "

To find Horse-Power of an Engine to Raise Water to a Given Height.

Weight of column of water × by its velocity, in feet, per minute; product ÷ 33,000 = H. P.

To find Velocity required to Discharge a Given Volume of Water in any Given Time.

Number of cubic feet × 144; product ÷ by area of pipe, or opening, in inches = velocity.

To find Area of Pipe, Velocity and Volume of Water being Given.

Proceed as above; divide product by velocity.

Locomotive Slide-Valve.

Lap = travel × 0.22 | Lead = travel × 0.07.

To Compute Stroke of a Slide-Valve.

To twice the lap add twice the width of steam-port in inches. Sum equal stroke.

To Ascertain the Breadth of the Ports.

Half the throw of the valve should be at least equal to the lap on the steam side, added to the breadth of the port. If this breadth does not give the required area of port, increase the throw of valve until the area is attained.

To Find Lap on Steam Side of Slide-Valve, to Cut Off Steam at any Given Part of Stroke of Piston.

From stroke of piston deduct length of stroke, which is to be made before steam is cut off; divide remainder by stroke of piston, extract square root of quotient; multiply this root by half throw of valve; from product subtract half the lead; remainder equals lap required.

Ex.—Stroke of piston, 60 ins.; stroke of valve, 16 ins.; lap upon exhaust side, ½ in. = $\frac{1}{32}$ of valve stroke; lap upon steam side, 3¼ ins.; lead, 2 ins.; steam to be cut off at $\frac{5}{6}$ the stroke. What is the lap?

$60 - \frac{5}{6}$ of $60 = 10$. $\frac{10}{60} = .166$. $\sqrt{.166} = .408 \times \frac{16}{2} = 3.264$, and $3.264 - \frac{2}{2} = 2.264$ ins., or the lap − half the lead.

To Compute Lap required on Steam Side of a Valve, to Cut Steam Off at Various Portions of Stroke of Piston.

Valve without Lead.

	Distance of Piston from end of stroke, when steam is cut off, in parts of length of its stroke.									
	1-2	5-12	1-3	7-24	1-4	5-24	1-6	1-8	1-12	1-24
Lap in parts of stroke...	.354	.323	.286	.27	.25	.228	.204	.177	.144	.102

Ex.—Take elements of the preceding case. Under $\frac{1}{6}$ is .204, and $.204 \times 16 = 3.264$ ins. lap.

When Valve is to have Lead—Subtract half proposed lead from lap ascertained by table; remainder will be proper lap for valve.

Ex.—If, as in the last case, the valve was to have 2 ins. lead, then $2 \div 2 - 3.264 = 2.264$ ins.

To find at what Part of Stroke of Piston any given Lap on Steam Side will Cut Off Steam.

To the lap on the steam side add the lead; divide the sum by half the length of throw of the valve. From a table of natural sines, find the arc, the sine of which is equal to the quotient; to this arc add 90°, and from their sum subtract the arc, the cosine of which is equal to the lap on the steam side, divided by half the throw of the valve. Find the cosine of the remaining arc, add 1 to it, and multiply the sum by half the stroke of the piston, and the product will give the length of that part of the stroke that will be made by the piston before the steam is cut off.

Ex.—Take elements as before.

$\frac{2.25 \div 2}{16 \div 2} = .53125$; sin. $.53125 = 32^\circ\ 5'$; $32^\circ\ 5' + 90^\circ = 122^\circ\ 5'$; $2.25 \div 8 = .28125 =$ cos. of $73^\circ\ 40'$; then $122^\circ\ 5' - 73^\circ\ 40' = 48^\circ\ 25'$; cos. $+ 1 = 1.66371$, which $\times \frac{60}{2} = 50$ ins $= \frac{5}{6}$ stroke.

The lap on the steam side should always be greater than on the exhaust side; difference greater the higher the velocity of the piston.

To find Distance of a Piston from End of its Stroke when Lead produces its Effect.

Divide the lead by the width of steam-port, both in inches, and term the quotient sine; multiply its corresponding versed sine by half the stroke; the product will give the distance of the piston from the end of its stroke, when steam is admitted for the return stroke and the exhaustion ceases.

Ex.—Stroke of a piston is 48 ins., width of port 2½ ins., and the lead ½ in. What will be the distance of the piston from the end of its stroke when exhaustion commences?

$.5 \div 2.5 = .2$ = sine, and versed sine of $.2 = .0202$; then $.0202 \times \frac{48}{2} = .4848$ *ins.*

To find the Lead, when Distance of a Piston from the End of its Stroke is given.

Divide the distance, in inches, by half the stroke, in inches, and term the quotient versed sine; multiply the corresponding sine by the width of the steam-port; the product will give the lead.

Ex.—Take elements of the preceding case.

$.4848 \div 24 = .0202$ = versed sine, and sine of versed sine $.0202 = .2$; then $.2 \times 2.5 = .5$ *ins.*

To find the Distance of a Piston from the End of its Stroke, when Steam is Admitted for its Return Stroke.

Divide the width of the steam-port, and also that width less the lead, by half the stroke of the slide, and term the quotient versed sines *first* and *second*; ascertain their corresponding arcs, and multiply the versed sine of the difference between the *first* and *second* by half the stroke; the product will give the distance required.

In using the above rules, all the dimensions are to be taken in inches; answer will be in inches.

From an inspection of these rules, it will be seen, *supposing there is no lead*, that the point of the stroke at which the steam is cut off is determined by the proportion which the lap on the steam side bears to the stroke of the valve. Whatever the absolute dimensions of the lap may be, it will follow in every case in which it bears the same ratio to the stroke of the valve, that the steam will be cut off at the same point of the stroke.

Portion of Stroke of Piston at which Exhausting Port is Closed and Opened.

Lap on the Exhaust Side of the Valve in Parts of its Throw.

Lap.	Portion of Stroke at which Steam is cut off.							
	1-3	7-24	1-4	5-24	1-6	1-8	1-12	1-24
A 1-8	.178	.161	.143	.126	.109	.093	.074	.053
1-16	.13	.118	.1	.085	.071	.058	.043	.027
1-32	.113	.101	.085	.069	.053	.043	.033	.024
0	.092	.082	.067	.055	.041	.033	.022	.011
B 1-8	.033	.026	.019	.012	.008	.004	.001	.001
1-16	.06	.052	.04	.03	.022	.015	.008	.002
1-32	.073	.066	.051	.042	.033	.023	.013	.004
0	.092	.082	.067	.055	.044	.033	.022	.011

The units in column of Table A express distance of piston, in parts of stroke, from end of its stroke, when exhaust port in advance is closed; those in column Table B, distance of piston, in parts of stroke, from end of its stroke, when exhaust port behind it is opened.

Example.—A slide-valve is to cut off at 1-6 from end of stroke of piston; lap on exhaust side is 1-32 of stroke of valve; stroke of piston, 20 inches. At what point of stroke of piston will the exhaust port in advance of it be closed, and one behind it opened?

Under 1-6, Table A, opposite to 1-32, is .053, which × by 20, length of stroke = 1.06 inches, and under B, opposite to 1-32, is 0.33, which × by 20 = .66 inches.

EXPANSION OF STEAM.

When air is compressed into a smaller volume, a certain amount of power is expended in making the compression, which power, as in the case of a bent spring, is given back when the pressure is withdrawn. If the air, when compressed, is suddenly discharged into the atmosphere, the power expended will be lost; hence there would be a loss of power in dispensing with that power, which is recoverable by the expansion of the air to its original volume.

Now, steam in an engine is in the condition of air already compressed; and unless the steam be worked in the cylinder expansively, which is done by stopping the supply from the boiler before the stroke is closed, there will be a loss of a certain proportion of power which the steam would otherwise produce. If the flow of steam to an engine be cut off at time when the piston has performed one-half the stroke, leaving remainder to be completed by the expanding steam, the efficacy of the steam will be increased 1.7 times beyond what it would have been had the steam at half stroke been dismissed without extracting more power from it.

The benefits of expansion are: steam being cut off at $\frac{1}{8}$ of the stroke, the efficacy is increased 3.2 times; at $\frac{1}{7}$ is 3 times; at $\frac{1}{6}$ is 2.8 times; at $\frac{1}{5}$ is 2.6 times; at $\frac{1}{4}$ is 2.4 times; at $\frac{1}{3}$ is 2.1 times; at $\frac{1}{2}$ is 1.7 times.

To Find the Increase of Efficiency Arising from Working Steam Expansively.

Divide the total length of the stroke by the distance (which call 1) through which the piston moves before the steam is cut off. The neperian logarithm of the whole stroke expressed in terms of the part of the stroke performed with the full pressure of steam, represents the increase of efficiency due to expansion.

Ex.—If steam be cut off at $\frac{2}{15}$ of the stroke, what is the increase due to expansion; $\frac{2}{15}$ of stroke = 7.5 of whole stroke? Log. of no. 7.5 is 2.015, which, increased by 1, the value of the

portion performed with full pressure, gives 3.015 as relative efficacy by expansion to this extent, instead of 1, which would have been the efficacy had there been no expansion.

Table to Compute the Expansion of Steam.

Portion of stroke at which steam is cut off, in eighths	1-8	2-8	3-8	4-8	5-8	6-8	7-8
Ratios of Expansion will be	8	4	2.66	2	1.6	1.33	1.14
Hyperbolic Logarithm	2.079	1.386	0.978	0.693	0.470	0.285	0.131

Portions of stroke at which steam is cut off, in tenths.	1-10	2-10	3-10	4-10	5-10	6-10	7-10	8-10
Ratios of Expansion will be.	10	5	3.33	2.5	1.66	1.42	1.25	1.11
Hyperbolic Logarithm	2.303	1.609	1.203	0.916	0.507	0.351	0.223	0.104

To compute the Mean Pressure of Steam of any given Initial Pressure, when cut off at any 1-8 *or* 1-10 *part of the stroke*—Divide the initial pressure of steam in lbs. per square inch by ratio of expansion, and multiply the quotient by the hyperbolic Log, increased by 1, of the number representing the ratio, which gives the mean pressure throughout the stroke, in pounds, per square inch. Thus, if steam of 100 lbs. be cut off at half stroke, ratio of expansion is 2, and $100 \div 2 \times 1.693 = 84.65$, which is the mean pressure throughout the stroke, in pounds, per square inch.

To find the Terminal Pressure—Divide the initial pressure by the ratio of expansion; thus, terminal pressure of steam of 100 lbs., cut off at half stroke, will be $100 \div 2 = 50$ lbs. per square inch.

For table of Mean Pressure, see page 252.

Effect of Expansion with Equal Volumes of Steam.

The theoretical economy of using steam expansively is as follows, a like volume of steam being expanded in each case, and expanded to fill the increased spaces. *No deductions are allowed for reduction of the temperature of th steam while expanding, or for loss by back pressure.*

Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain per cent. in Fuel.	Point of Cutting Off.	Expansion Number.	Mean Pressure of Steam.	Gain per cent. in Power.
.1	10.	3.302	230.	.5	2.	1.693	69.3
.125	8.	3.079	208.	.6	1.66	1.507	50.7
.166	6.	2 791	179.	.625	1.6	1.47	47.
.2	5.	2.609	161.	666	1.5	1.405	40.5
25	4.	2.386	139.	7	1.42	1.351	35.1
.3	3 33	2.203	120.	.75	1.33	1.285	22.3
333	3.	2.099	110.	.8	1.25	1.223	20.5
.375	2.66	1.978	97.8	.875	1.143	1.131	13.1
.4	2.5	1.916	91.6	.9	1.11	1.104	10.4

The same relative advantage follows in expansion, as above given, whatever may be the initial pressure of steam.

Gain in Fuel, and Initial Pressure of Steam Required when Acting Expansively, Compared with Non-Expansion or Full Stroke.

Point of Cutting Off.	Gain in Fuel.	Initial Pressure Required.		Point of Cutting Off.	Gain in Fuel.	Initial Pressure Required.	
		Cutting Off.	Full Stroke.			Cutting Off.	Full Stroke.
Stroke.	Per cent.	Stroke.	Stroke.	Stroke.	Per cent.	Stroke.	Stroke.
7/8	11.7	1.01	1.	3/8	49.6	1.32	1.
3/4	22.4	1.03	1.	1/4	58.2	1.67	1.
5/8	32.	1.09	1.	1/8	67.6	2.6	1.
1/2	41.	1.18	1.				

The relative effect of steam during expansion, is obtained from the preceding rule.

The mechanical effect of steam in a cylinder = mean pressure of steam in lbs. × distance through which it has passed in feet.

The pressure at the end of stroke, or at any given point of stroke, = initial pressure ÷ the portion of the stroke performed when steam is cut off.

The per cent. of gain by expansion = relative expansion × 100.

Back pressure, is the force of the uncondensed steam in a cylinder opposed to the course of a piston, caused by impossibility of obtaining a perfect vacuum, and it varies from 3 to 5 lbs. per square inch.

Ex.—*The initial pressure of steam admitted to a cylinder having a stroke of 9 feet is 50 lbs. per square inch, cut off at ⅓ the stroke, the back pressure being 2 lbs.; what is the relative effect of the steam, its mechanical effect, its pressure at the end of the stroke, at ⅔ of the stroke, and the gain per cent.?*

(Hyp. log. $9 \div 3) + 1 = 2.099$ *relative effect.*

$2.099 \times 50 - 2 \div 3 = 33.25$ lbs., and $9 \times 33.25 = 299.25$ lbs. *mechanical effect.*

$\frac{50-2}{3} = 16$ lbs. *at the end of the stroke.*, $\frac{50-2}{2} = 25$ lbs. at ⅔ the stroke $1.999 \times 100 = 109.9$ per cent.

The above results are theoretical. In practice, the back pressure and loss of temperature by cooling, friction in the steam passages, materially reduce the results.

Gain in Fuel.

When steam is cut off before the end of stroke of a piston, the pressure effected by it for the portion at which it flowed for full stroke, is represented by 1, and the pressure exerted afterward by the result due to the relative expansion. The total pressure or work is represented by the sum of these units. If the steam had flowed for the full stroke of the piston, the pressure would

have been 1 added to the proportionate distance for which the steam was expended in case of expansion.

Ex.—*What are the relative pressures, or work, effected in steam cut off at ½ and ¾ stroke, and at full stroke?*

Cut off at ½, by rule and table = 1.693; then, 1 + 1 = 2, and 2 and 1.693 the *relative effects.*

Cut off at ¾, by rule and table = 1.285; then, 1 + .33 = 1.33, and 1 33 and 1.285 the *relative effects.*

At full stroke, 1 + .33 (the proportionate distance of ¼ in ¾) = 1.33, the relative effect.

To Compute the Gain in Fuel.

Divide the relative effect of the steam by the number of times the steam is expanded, and divide 1 by the quotient; the result is the initial pressure of steam required to be expanded to produce a like effect to steam at full stroke. Divide this pressure by the number of times the steam is expanded, and subtract the quotient from 1; remainder will give the gain per cent. in fuel.

Ex.—*When steam is cut off at ½ stroke of piston, what is the gain in fuel?*

Relative effect = 1.693; number of times of expansion = 2; 1.693 ÷ 2 = .8465, and 1 ÷ .8465 = 1.18, *initial pressure;* 1.18 ÷ 2 = 59, and 1 − 59 = 41 *per cent.*

To Calculate Power of a Blowing Engine.

P = pressure of blast, in pounds, per square inch.
A = area of cylinder in square inches.
V = velocity of piston, in feet, per minute.
f = friction of piston, and from curves, pipes, etc., taken at 1.25 lbs. per square inch of piston.
f = power in pounds, to be raised 1 foot per minute = P A V f.

$$\text{Horse-power required} = \frac{P\,A\,V\,f}{33{,}000}$$

If cylinder is double-acting, divide result by 2.

Table of Nominal Horse-Power of High-Pressure Engines.

$$Formulæ \ \frac{d^2 v}{1{,}000} = \text{H. P.}$$

H. P.	Diam. and Stroke of Cylinder.		Revolutions.	H. P.	Diam. and Stroke of Cylinder.		Revolutions.
No.	Ins.	Ft.	Per Min.	No.	Ins.	Ft.	Per Min.
9.	6 ×	1.	125	64 8	15 ×	3.	48
12.	7 ×	1.	125	67.5	15 ×	5.	30
12 5	7 ×	1.5	85	77.8	16 ×	4.	38
16 3	8 ×	1.5	85	100.	18 ×	4.5	34
21 1	9 ×	1.5	87	128.	20 ×	5.	32
26.	10 ×	1 5	87	130.	20 ×	6.5	25
27.	10 ×	2.	68	154.4	22 ×	5.	32
29.	10 ×	4	36	160.7	22 ×	6.	28
34.	11 ×	2.	70	184.	24 ×	5.5	29
34.	11 ×	3.5	40	199.	24 ×	7.5	24
40.	12 ×	2.	68	225.	26 ×	6.	28
40.	12 ×	3.	47	275.	28 ×	7.	25
55.3	14 ×	3.	47	315.	30 ×	7.	25
60.	14 ×	4.5	34	340.	30 ×	9.	21

The above table of horse-power divided by 3 will give nominal horse-power of condensing engines of similar dimensions.

$$Formulæ \ \frac{d^2 v}{3{,}000} = \text{H. P.}$$

Power necessary to Grind Grain with Portable Mills.

Horse Power.	Size of Stones.	Revolutions per Minute.	Bush. Corn Ground per Hour.	Bushels of Wheat Ground per Hour.
2 to 4	12-inch.	800 to 900	1 to 4	1 to 3
4 " 6	20 "	650 " 700	5 " 8	4 " 6
6 " 8	30 "	550 " 600	10 " 15	7 " 10
8 " 12	36 "	450 " 500	18 " 25	12 " 15
12 " 15	48 "	350 " 400	25 " 35	15 " 18

TABLE OF PORTABLE ENGINES.

Cylinder.		Boiler.							Balance Wheel or Driving Pulley.				
			Furnace.			Tubes.							
Diameter. Inches.	Length of Stroke.	Shell of Boiler. Inches.	Length.	Width.	Height.	No.	Diam. Inches.	Length Inches.	Diameter. Inches.	Face of each Pulley. Inches.	Revolutions per Minute.	Horse Power.	Weight. Lbs.
4	10	24	38	20	18	14	3	48	30	6	175	3	2,800
5	10	26	32	22	28	15	3	48	36	7	175	5	3,200
5½	10	26	34	24	28	18	3	50	40	7	175	6	3,800
6	10	28	38	24	28	22	3	54	42	7	175	7	4,200
7	10	30	38	25	30	24	3	56	44	8	175	8	4,900
8	10	33	40	26	32	28	3	60	44	8	175	10	5,400
8	12	33	42	29	32	34	3	72	48	8	150	12	6,100
9	12	34	42	30	34	36	3	74	48	9	150	15	6,900
9½	12	36	42	32	36	38	3	78	48	10	150	18	10,000
10	16	38	46	34	42	42	3	78	60	10	115	20	11,200
11	18	38	52	34	47	46	3	84	66	10	100	25	12,300
12	18	40	54	36	48	50	3	84	60	12	100	30	13,800
14	18	42	56	38	50	54	3	88	66	14	100	40	16,200

Rumpa Wheel and Foundry Co.

Power required for Various Purposes.

To drive a 20 to 30-inch circular saw.....	4 to 6 horse power.
" " 32 to 40 " "	12 "
" " 48 to 50 " "	15 "
" " 50 to 62 " "	25 "

Threshing Grain.

4 horse-power will thresh 50 bushels per hour.

6 to 8 horse-power will drive the ordinary 10 to 12-horse thresher and separator.

Ginning Cotton.

4 horse-power will drive a gin of from 40 to 60 saws; and for every additional 20 saws add 1 horse-power.

STEAM BOILERS.

The number of square feet of heating or flue surface required to evaporate a cubic foot of water per hour, which is equivalent to an actual horse-power, in—

Cornish boilers = 70 square feet.
Land and marine = 8 to 11 square feet.
Locomotive boilers = 5 to 6 square feet.

Number of Square Feet of Heating Surface per Square Foot of Fire Grate.

Wagon boilers.....	13 to 15 square feet.
Cornish boilers.....	40 "
Locomotive boilers.....	80 "

Locomotive Boilers.

Water evaporated in cubic feet per hour equals area of heating surface in square feet, squared, divided by area of fire grate in square feet, the sum multiplied by .0022.

at *a*, affording increased room for escape of steam when valve is raised; H, an auxiliary chamber; I I, valve seats in outer cylinder, A. K is a double-seat valve, or inner hollow cylinder, the upper foot, *k*, of which projects beyond the lower foot, *k*, and having an annular recess, L, with a shoulder at *m*, against which the steam presses, thereby aiding the steam to raise the valve from its seat. *n* is a large open space in valve, K, through which the steam entering at the lower valve seat escapes. The upper end, *n*, of the valve, K, is enlarged, with transverse bar, O, with boss, *p*, for reception of stand, R, fulcrum, S, weighted lever, T, for holding the valve to its seats. The mechanism for holding the valve to its seat is diminished in size and movement to one-eighth of that of the ordinary apparatus used; its operation being, the combined cylinders, A K, being fastened to the steam boiler, the steam enters by the perforations, *f f*, filling the annular chamber, E L, and pressing against the shoulder, *m*, of the valve. Now, as the force exerted by the steam on the valve exceeds the working pressure, the valve, K, will be raised from its seats, and the surplus steam allowed to escape from the boiler through the circular space between the cylinders, as well as through the large interior of the valve, K, by means of which the pressure of the steam is immediately regulated, besides allowing nearly double the amount of steam to escape, as compared with the ordinary valve.

They are adapted to locomotive, marine, and stationary engines, and, with very slight alterations, can be made secret or lock-up valves. Address

JOHN ASHCROFT,

50 and 52 John Street, New York.

ASHCHOFT'S

PATENT LOW WATER DETECTOR,

For Preventing the Explosion or Burning Out of Steam Boilers

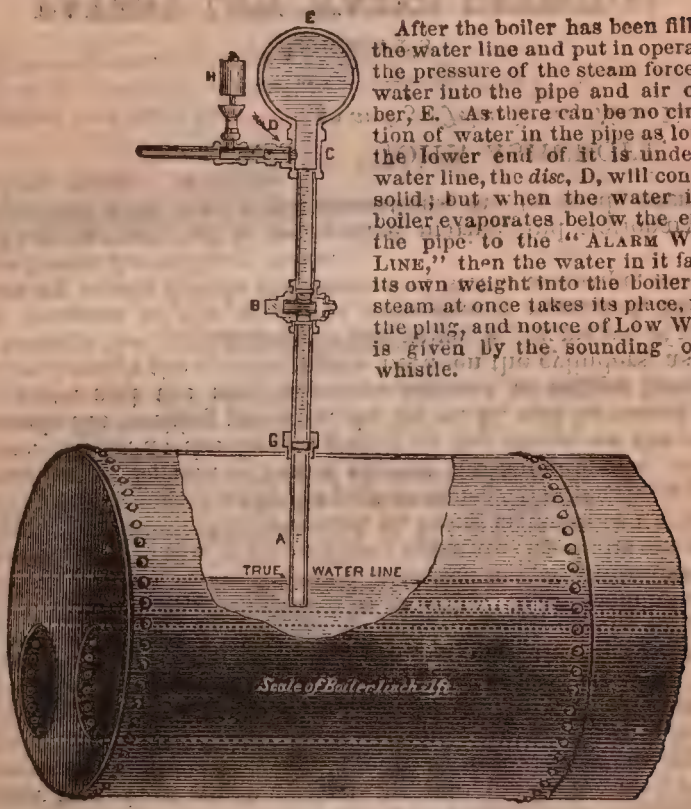
This instrument is made of a piece of one-inch gas-pipe, A, an air-chamber, E, a disc of fusible metal, D, fusible in boiling water, which is secured to its seat by a union having a

---

Ramapo Wheel and Foundry Co.

whistle on its stem (as represented in the cut). The union, G, connects the Detector to the boiler. Its operation is solely upon the natural laws of gravitation and heat, having no mechanical appliances to get out of order, and not depending on the uncertain contraction or expansion of metals.

Its action is as follows:



After the boiler has been filled to the water line and put in operation, the pressure of the steam forces the water into the pipe and air chamber, E. As there can be no circulation of water in the pipe as long as the lower end of it is under the water line, the *disc*, D, will continue solid; but when the water in the boiler evaporates below the end of the pipe to the "ALARM WATER LINE," then the water in it falls of its own weight into the boiler, and steam at once takes its place, melts the plug, and notice of LOW WTAER is given by the sounding of the whistle.

TO RECHARGE THE DETECTOR.

1st—After the disc has melted, shut the cock and pump the water to the line above the end of the pipe.

2d—Remove the union, put in the disc, and screw the union firmly against it. Observe that it does not leak.

No packing of any kind must be used about the disc; if it is properly refixed, it will not drip.

3d—Open the cock, at first cautiously, to give the water time to cool before it reaches the disc; otherwise it might melt. In fifteen minutes open the cock full.

INSTRUCTIONS FOR APPLYING THE LOW WATER DETECTOR.

Blow off the steam and reduce the water in the boiler to the centre or below; then fill up with cold water to the ALARM WATER LINE; this will reduce the heat of the boiler at once, so as to allow the workmen, without delay, to drill and tap the boiler for the union, G. Be particular and cut the inside pipe so that the lower end will just touch the line above mentioned when the union to which the pipe is attached is firmly screwed in.

This Instrument can be safely tested at any time by allowing the water to fall by evaporation to the ALARM WATER LINE. After the alarm is given the water may be pumped into the boiler to its proper height with perfect safety. The ALARM WATER LINE should be at least *one inch* above the highest fire surface.

More than 8,000 of them are in use in the United States.

Invented and for sale by

JOHN ASHCROFT,
50 *and* 52 *John Street, New York.*

MOUNTINGS FOR A NOMINAL 30 HORSE-POWER BOILER.

(*English.*)

Manhole oval, 18 ins. × 15 ins.
Vacuum valve, 2½ ins. diameter at seat.
Spring balance safety valve, 2½ ins. diameter at seat.
Weighted safety valve, 5 ins. diameter at seat.
Escape valve, 2½ ins diameter at seat.
Damper area of opening, 4 ft. × 1 ft. 1½ ins.
Damper weight, 8 ins. × 10 ins. × 4 ins.
Blow-off cock, 3-in. bore.
Range of glass gauge, 10 ins.

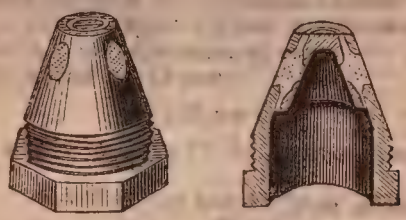
PROPORTION OF COCKS.

B = the bore of the cock.
Bottom diameter of plug = B × 1¼.
Length of plug from bottom = B × 3.
Length of handle = B × 6.
Taper of plug ¼ inch to each inch of length.

SMITH'S FUSIBLE SAFETY-VALVE OR PLUG.

These plugs are designed not only to guard against the evil effects of low water, but also against high steam; for if the pressure be run up to, or a little above that marked on the plug, the plug will fuse and blow out, though there may be an ample supply of water. The plugs are made to screw into the boiler, either from the fire side or water side.

This plug is adopted by the National Boiler Insurance Co., of Manchester, England, and has proved invaluable in saving many boilers from explosion.



It consists of an outer cone of brass, with openings on top and sides, as shown in cut; within this is placed another brass cone, with corresponding openings; between them a lining of fusible metal is poured, which, filling the apertures, binds the two cases together. The metal is so compounded as to melt at given temperatures.

When the water in the boiler becomes low, or its temperature unduly increased, the fusible metal melts, allowing the inner cone to fall out, thus relieving the excess of pressure in the boiler.

In ordinary lead plugs, the more fusible metal strains through the mass, leaving a sponge of lead in the boiler, which is expected to relieve the undue pressure; while with this improved plug, by the melting of the lining the inner cone is immediately detached, giving an opening of at least 1¼ square inches for the escape of the steam.

The threads of these plugs are cut to the standard *Gas Tube* thread and to a corresponding gauge; so that wherever a gas thread tap of the proper size can be obtained, the plugs are very readily applied.

WHERE TO FIX THE PLUG.

The plug should always be placed at the point of highest fire surface, exposed to intense action of the fire, and, if possible, so located that while the water covers the plug on the one side, the fire will act directly upon the other side; the latter condition may, and in some forms of boilers must be omitted.

In *Locomotive Boilers*, and other fire-box boilers where access cannot be conveniently had from the water side, the plug made as shown in Fig. 2, will be screwed in from the fire side, and should be located in the crown of the furnace, about two-thirds the length of the grate, back from the fire door. In the *Ordinary Return Flue* Boiler, locate it either on the top of the flue at the back end, or screw it into the back head at the proper height.

In the low-pressure *upward return flue* boilers, they should be located in the crown of the back connection, and a short distance from flue-head. In the *return tubular* low-pressure boiler, they should be located same as in return flue boilers.

In the cylindrical shell, return tubular boiler, set in masonry, the plug should be screwed into the back tube head at the proper height.

In the *plain cylindrical* boiler they may be put in over the grate bars, by setting a tube into the boiler of such length as to place the plug at the proper height, or the plug may be screwed into the side sheet at the proper height. Where more than one cylinder boiler are set together, and the plug is put at the side, it should be screwed into the side next the adjoining boiler.

As a very slight change in the properties and manipulation of the fusible alloy will affect its fusing point, there must always be a little margin allowed for the pressure marked on the plug. When a plug has been melted out, it should be either returned to the manufacturer to be refilled, or apply to him for the metal to refill, and directions: giving, at the same time, the number of the plug and the pressure marked upon it. In all cases a spare plug or cap should be kept on hand, to be applied in case of the one in use giving out.

Whenever the boiler is cleaned, the plug should be well cleaned on both sides, or removed and the spare one applied in its place.

For further information, apply to

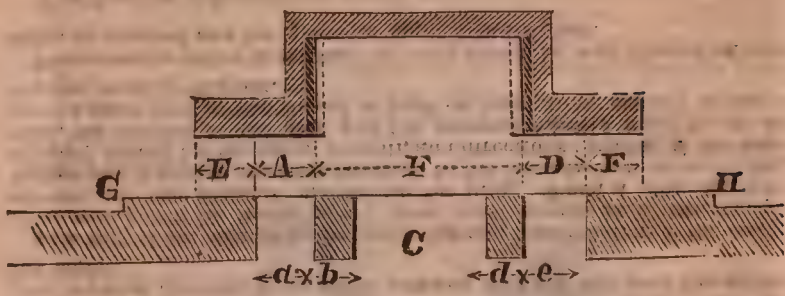
WILLIAM G. HAMILTON,

24 Broadway, New York.

Ramapo Wheel and Foundry Co.

THE SLIDE VALVE.

Definition of its Parts, Motion, and Functions.



G H is the valve face.
A D the steam ports.
b d the bars.
C the exhaust port.

A E D F the faces of the valve.
E F the outside lap.
B the exhaust cavity.

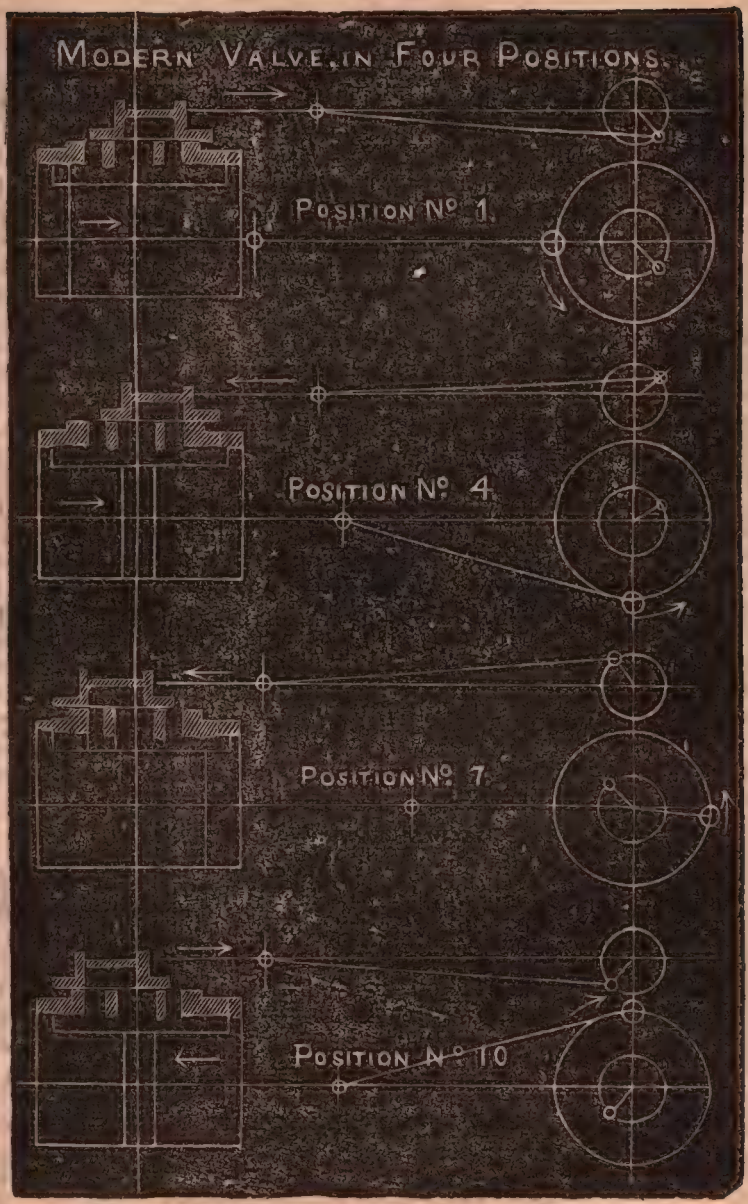
The width of the opening of the steam ports, for the admission or for the release of steam, at the beginning of the stroke, is known as *Lead;* on the steam side it is denominated outside lead, or lead for the admission; on the exhaust side it is *Inside Lead*, or lead for the exhaust.

When the valve is placed at half stroke over the ports, the amount by which it overlaps each steam port, either internally or externally, is known as *Lap;* on the steam side it is named *Outside Lap;* on the exhaust side, *Inside Lap.*

When the terms *Lap* and *Lead* are employed alone, they designate the outside lap and lead.

The *Advance* of the *Eccentric* denotes the angle which the eccentric forms with its position at half-stroke, when the piston is at the commencement of its stroke, and is called *Angular Advance.*

The *Advance* of the *Valve* denotes the amount by which the valve has travelled beyond its middle position, when the piston is at the end of the stroke, and is known as *Linear Advance,*



Ramapo Wheel and Foundry Co.

and is equal to the sum of the outside lap and lead, and to the inside lap and lead.

When the valve is so formed that, at half stroke, the faces of the valve do not close the steam ports internally, the amount by which each face comes short of the inner edge of the port, is known as *Inside Clearance*. In the diagram, inside lap is shown by the dotted lines, the exhaust cavity B being reduced to the dotted lines. Were the faces shortened, as shown by the darkened lines, the difference would be Inside Clearance, the exhaust cavity B being enlarged an equal amount.

Motion of the Valve and Functions.

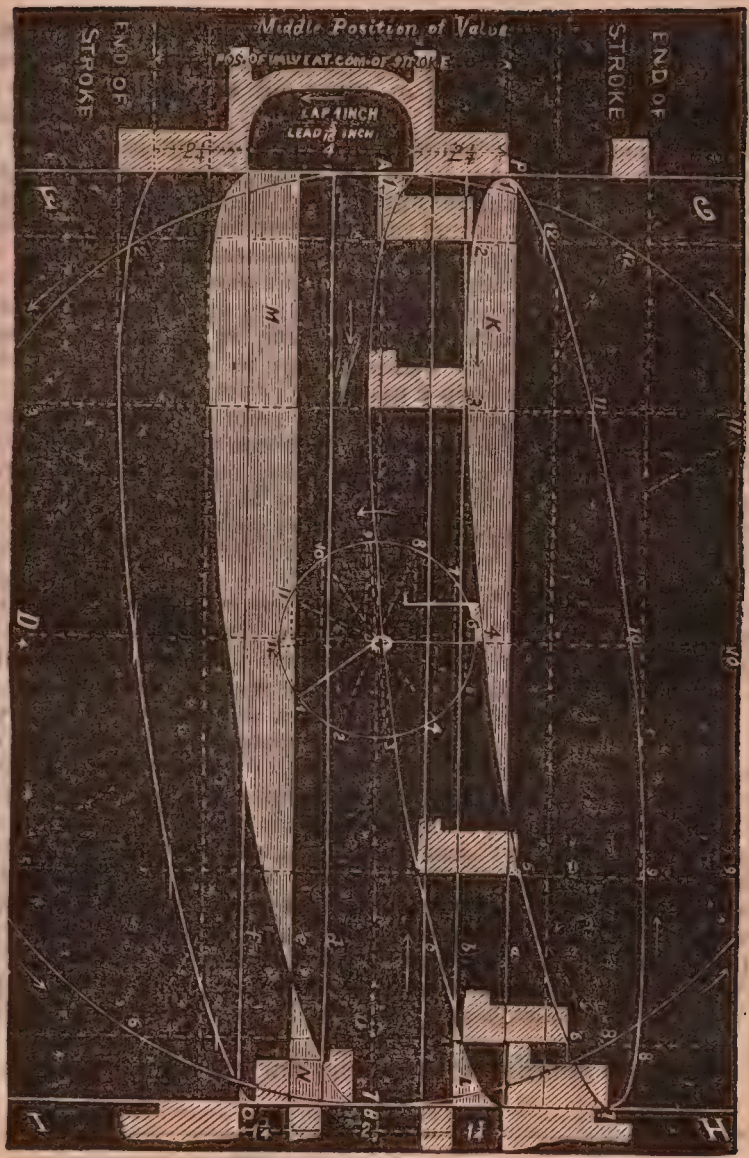
The four positions of the valve, corresponding to the four quarters of a revolution of the crank-pins, are shown in the annexed diagram, page 295.

No. 1.—The position is at the front end of its stroke, and the eccentric is placed in advance of being at right angle with the crank, a distance equal to the lap and lead. Say, lap 1 inch, lead 5-16 = 1 5-16 from the vertical centre line.

In No. 4, in which the crank has only completed one-quarter of a revolution, the eccentric has not only completed its throw, but has also gone on its return throw an amount equal to the angular advance. The valve, therefore, has attained the end of its path, or given full port to the steam, some time before even the first half of the throw of the crank has been completed, and is already returning to close the port. In position No. 7, in which the crank is at the commencement of the return throw, the valve has not only closed the front steam port, it has also admitted the steam for the back stroke, and released the steam employed in the front stroke of the piston. All this it has done some time before the end of the front stroke.

When the position No. 10 is attained, the eccentric has completed its retrograde movement, and consequently that of the valve has recommenced its forward throw in the direction in which it set out from position No. 1.

To point out the peculiarities of the valve motion, relatively to that of the piston, position of the eccentric, and to define the points of the stroke at which the principal events of the distribution take place, and to place them on paper, the diagram generally employed is as follows:



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Method of Laying Out Diagram of Motion of Valve.

Draw A B equal to the length of the stroke of the piston, and bisect at C. From C as a centre, with C A as a radius, describe circle A B to represent path of the crank-pin; and from C as a centre, with the radius of the eccentric, describe a smaller circle, as the path of the centre of the eccentric. Draw a perpendicular line, D E, through the centre C, and construct a square, F G H I, upon the greater circle; consider H I as the level of the valve face; set off, equally on both sides of the centre line A B, the width of the ports and the bars; and parallel to A B draw lines, *a b c d e f*, across the figure from the edges of the ports as determined.

As the motion of the valve is the counterpart of the longitudinal movement of the eccentric, all that is necessary to determine the position of the valve at any part of the stroke, or angle of the crank (angularity of connecting and eccentric rods being neglected), is to find the position of the eccentric in its circular path.

Let the vertical movement of the eccentric be reckoned in the direction of the line D E, and the horizontal movement in the direction of the line A B, then it is obvious that when the centre of the eccentric lies in the line D E, either above or below the centre C, the eccentric is midway in its horizontal movement, and the valve must be simultaneously in its middle position. The vertical line D E is then a datum line from which to measure the motion of the eccentric, either way, toward the right or the left. The horizontal or effective movement of the eccentric is defined by its lateral motion parallel to the line A B, the motion of the valve along the valve face is represented on the diagram by its transverse motion parallel to the assumed valve face H I. The diagram thus shows the direction of the motion of the eccentric as at right angles with that of the motion of the valve, though not so in fact; it does not affect the integrity of the method of illustration, being a mere matter of arrangement.

Let us now assume the crank to be in position C A, at the commencement of a revolution being first position, Fig. I. The steam edge of the valve is therefore 1 5-16-inch (1-in. lap, 5-16

lead) from its middle position; this imports that the centre of the eccentric is also removed an equal amount from the datum line D E, and lies at the point I, in the smaller circle. The radius C I is then the position of the radius of the eccentric at the commencement of the stroke of the piston, and is the same as that of the eccentric in No. 1, Fig. I. Divide the large and small circles each into twelve equal parts, numbered in succession from the point I in the direction of the circular motion, and draw lines to the centre from the points of division; the lines so drawn represent the successive simultaneous positions of the crank and eccentric; also the transverse lines drawn through the points of division in the large circle, parallel to E D, represent the corresponding progressive positions of the crank during the front and back strokes, while the perpendiculars drawn to the datum line E D from the points of division in the smaller circle, measure the simultaneous lateral movements of the eccentric. As the lateral movement of the eccentric measures directly the motion of the valve, set off, on the transverse line K L, the distance *i* 2′ equal to the perpendicular from the point 2 in the smaller circle; then 2′ is the position of the edge of the valve, when the crank pin is at 2. Set off in the same way K 3′, L 4′—*m* 5′—*n* 6′ for the succeeding positions of the valve relative to the crank during its first half revolution. Set off, also, the distances 7′ for the commencement of the second half revolution, and the succeeding positions 8′—9′—10′—11′—12′. These positions range in an elliptic curve. Draw the curve complete, it defines the twelve positions, and all intermediate positions of the valve; thus showing in one view the whole routine of the valve motion—admission, expansion, release, and compression—which cannot be possibly obtained by models or other devices.

To render the action of the valve more apparent, as regards the distribution of the steam, the motion of the steam side, during the admission of the steam for the front stroke, is defined by dark-shading K, between the line *a* and the elliptic curve. The motion of the valve for releasing the steam on the front side, toward the end of the stroke, is distinguished by shading L. On the other side of the piston, during the front stroke, the cylinder is wide open to the exhaust, as indicated by

shading M, and is only closed toward the end of the stroke at the point where the elliptic curve crosses the line *e*. As the waste steam is from this point locked up in the cylinder, and is subjected to compression by the advancing piston, until the port is opened for admission, the triangular shaded space N represents the period of compression. Just before the completion of the front stroke, when the piston was about 5-32 inch yet to describe, the opposite steam side of the valve opens the port for the admission of steam for the commencement of the back stroke, at the intersection of the elliptic curve with the line *f*. The period of admission against the piston is distinguished by the very small triangular shaded space O, at the termination of which the port is open 5-16 inch for the commencement of the back stroke, The same triangular allowance for the commencement of the front stroke is observable at the opposite corner of the diagram P.

How Distribution of Steam is Controlled.

From the nature of valve motion, it follows that the distribution is controlled by the *outer* and *inner edges* of the *extreme ports* and of the *valve*. The mere width of the exhaust port or thickness of bars is immaterial to the timing of the distribution.

The *extreme edges* of the steam ports, and those of the valve, regulate the *admission* and *suppression;* and the *inner edges* of the ports, and the valve, command the *release* and the *compression*.

For every stroke of the piston, four distinct events occur—the admission, the suppression, the release, and the compression.

Influence of the Connecting Rod.

Under the influence of the connecting rod, the piston is placed in advance of its progress due to the crank alone, throughout the front stroke, and is behind its due position at all parts of the back stroke.

Lead of Valve.

By the provision of *lead*, some time is allowed for the exhaust steam to escape, previous to the end of the stroke, and

the steam from the boiler to enter the cylinder for the succeeding stroke.

Lap of Valve.

Lap of valve provides expansive action of the steam. Without lap there could be no expansion, because the suppression and release occur at the same time—not considering expansion, the effect produced on the piston by the unequal flow of steam into the cylinder, caused by the varying speed of the piston during the progress of a stroke of the crank.

Period of Expansion of Steam.

Expansion of steam in the cylinder takes place during the interval between the suppression and the release of the steam admitted.

Lap and Lead of Valve.

Lap and Lead procure an early and efficient release, because the lead of the exhaust, or the amount by which the valve is open to the exhaust, at the end of the stroke, is increased by as much as the addition of lap on the outside. Expansion increases with diminution of admission. Inside lap, by deferring the point of release, prolongs the expansion. It likewise increases the period of compression to the same extent that the release is deferred.

Inside Clearance of Valve.

Inside clearance operates reversely by hastening the release, it shortens the expansion; it shortens, also, the period of compression.

Lap, Lead, and Travel of Valve.

As lap, lead, and travel regulate the distribution of steam, an alteration of any one of these affects it in a definable manner. If they be equally varied in conjunction, the distribution remains the same.

Friction of the Slide-Valve.

The great aim of all engineers has been to remove the weight caused by the pressure of the steam, from the back of the slide-valve; but it has been considered almost impossible to produce a frictionless slide-valve.

All engineers agree that there is a great loss of power in working the slide-valve, but differ in the amount, from the fact that no correct data had been formed to make the calculations from.

Mr. Thomas Adams (see Engineering Facts, 1866) found, by careful experiments, that Locomotive No. 47, North London Railway, of 17-in. cylinder; 24-in. stroke; lap of valve, ⅞-in.; lead, ½-in.; travel, 4-in.; position of gear, 4th notch from middle gear, there being 5 notches for fore and back gear from the central one; drivers, 5 feet 6 inches diameter; boiler pressure, 160 lbs. per square inch;

	Horse Power.
That the actual horse-power of both cylinders was	840.532
That the friction of both valves was	54.952
" " " eccentrics	74.326
Total friction of eccentrics and valves	129.251

or 15 per cent. of the power of the engine required to move them.

The percentage of the friction of the valve, compared with percentage of the cylinder's power, ranges between 10 and 55 per cent., according to the variation of the position of the gear; for while the cylinder decreases in power, the friction of the valve and eccentrics increase until they absorb upwards of half the power of the cylinders.

The following cuts represent an *Equilibrium Piston Valve*, T. S. Davis' Patents.

Figs. 1 and 2 are the valve-case. Figs. 3 and 4 the valves.

The steam enters the outer chest from the boiler, and almost entirely surrounds the case, in which the valve moves, insuring an equal expansion of all parts, and preventing the sticking of the valve.

Fig. 1.

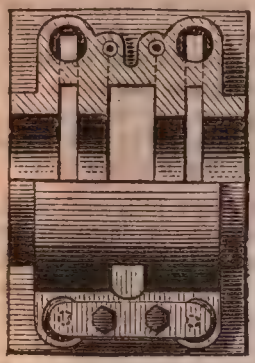


Fig. 2.

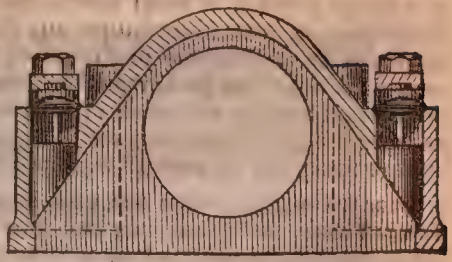


Fig. 3.

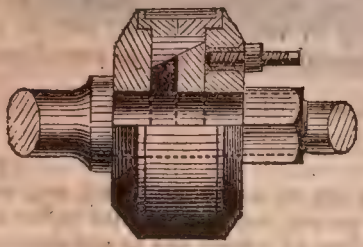


Fig. 4.

The full pressure of the steam is exerted on the outside ends of both valves, and exhausted between them, consequently balancing them under the heaviest pressure of steam, so that a child can move them. In locomotives relief valves are used to prevent excessive back pressure when reversing. The cuts, Figs. 3 and 4, show how the valves are made, and adjusted by set screws. This valve has been largely introduced in propeller, stationary, and locomotive engines; wears well, remains tight, and gives the best results.

The engine driving the works of the RAMAPO WHEEL AND FOUNDRY CO. is on Mr. Davis' principles of valve and cut-off, gives most economical results, and is a simple, efficient engine.

Memoranda of the Link Motion.

The *Stationery Link* gives a *constant lead.*

With *Shifting Link*, the *lead varies* with the *expansion.*

The greater the expansion, that is, the less the admission, the greater is the lead—least in full gear, most in mid gear.

The lead may be made the same for front and back strokes, by circling the link to the radius of the eccentric rod.

The linear advance of the eccentrics, with the stationary link, is always less than that of the valve, and is effected by the length of the eccentric rods.

With shifting link, the linear advance of the valve is in all cases equal to that f the eccentrics in full gear, independently of the length of the rods; by full gear is meant that the fore rod is brought into the centre line of the valve rod. In other positions the linear advance of the valve varies precisely with the lead.

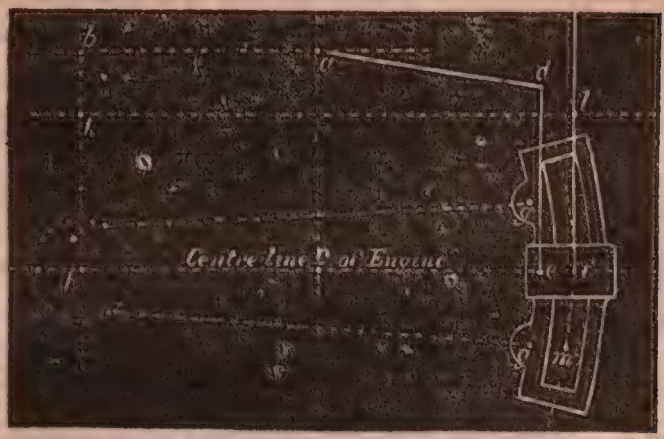
Motion of the Link

is composed of the distinct motions of the eccentrics, and every part of the link is subject to the same influence. The motion of the eccentric prevails in that half of the link to which it is coupled; at the centre the motion of the link is equally composed of the two.

The horizontal motion of the link, communicated by the joint action of the eccentrics, is a minimum at the centre of its length, when it is equal to twice the linear advance, and increases toward the extremities. Thus various periods of admission are attainable, by shifting the link on the block, on the general principle that admission varies with the travel of the valve.

The shorter the eccentric rods the greater is the front admission, and the less is the admission for the back. The quality of the motion derived from the link is modified by the position of the working centres, and most especially of the centre of suspension and connection. The centre of suspension is the most influential of all in regulating the admission; and its transition horizontally is much more efficacious than a vertical change of place, to the same extent.

DIMENSIONS OF LINK-MOTION.



TANK ENGINE.

Cylinder, 12 x 22 ins.; throw of eccentric, 3 ins.; travel of valve, 5 ins.; outside lap of valve, ½ in.; inside lap of valve, ¼ in.; radius of centre of link, 60 ins.; $a\,c = 10\frac{1}{2}$ ins.; $a\,b = 43$ ins.; $a\,d = 16$ ins.; $d\,e = 10$ ins; $g'\,g' = 8\frac{3}{4}$ ins.; $e\,f = 1\frac{5}{8}$ ins.; $g'\,m = 2\frac{7}{8}$ ins.

Right Side.		FORWARD MOTION.			*Left Side.*
Lead.	Opening.	Cut Off, Forward Stroke.	Lead.	Opening.	Cut off, Back Stroke.
1-16	2 3-32	20 7-8	1-16	1 15-16	21
1-4	11-16	16	1-4	5-8 full.	16 1-4
9-32	15-32	12 1-8	9-32	7-16	12 3-8
1-4 full.	5-16	8	1-4 full.	5-16	7 7-8

Right Side.		BACK MOTION.			*Left Side.*
1-16	2 3-32	20 7-8	1-16	1 15-16	21 1-8
1-4	11-16	16	1-4	11-16	16 3-8
1-4 full.	7-16	12	1-4 full.	7-16	12 1-8
1-4	5-16	8	1-4	5-16	8 1-4

VALVE MOTION

For cylinder, 16 x 24 ins.; travel of valve, 4½ ins.; outside lap of valve, ¾ in.; inside lap of valve, 1-16 in.; radius of centre of link, 68 ins. $a\,c$ = 12⅜ ins.; $a\,b$ = 51¾ ins.; $a\,d$ = 16 ins.; $d\,e$ = 14 ins.; $k\,l$ = 68 ins.; $k\,h$ = 8 ins.; $g\,g$ = 11 11-16 ins.; $e\,f$ = ½ in.; $g\,m$ = 2⅞ ins.

Forward Motion—Right Side.							Back Motion—Right Side.						
Lead	Opening.	Cut Off, F.	Lead	Opening.	Cut Off, B.	Diff.	Lead	Opening.	Cut Off, F.	Lead	Opening.	Cut Off, B.	Diff.
1/16	1½	20 5/8	1/16	1 9/32	20 9/16	1/16	1/16	1 3/8	20 15/16	1/16	1¼	20 7/8	1/16
1/8	15/16	17 15/16	1/8	7/8	18 1/16	1/8	1/8	7/8	18 3/16	1/8	2 7/32	18 7/16	1/4
5/32	23/32	16	5/32	21/32	16	...	5/32	21/32	16 1/8	5/32	5/8	16 5/16	3/16
3/16	9/16	14 1/16	3/16	17/32	14	1/16	3/16	1/2	14	3/16	1/2	14 1/16	1/16
3/16	7/16	12	3/16	7/16	12	...	3/16	13/32	11 13/16	3/16	13/32	11 7/8	1/16
7/32	11/32	10 1/16	7/32	11/32	9 15/16	1/8	7/32	11/32	9 11/16	7/32	11/32	9¾	1/16
7/32	5/16	8 1/16	7/32	9/32	7 15/16	1/8	7/32	9/32	7¾	7/32	9/32	7⅝	1/8

Forward Motion—Left Side.							Back Motion—Left Side.						
1/16	1½	20⅝	1/16	1 7/32	20½	1/8	1/16	1 3/8	20 15/16	1/16	1¼	20 13/16	1/8
1/8	15/16	18	1/8	7/8	18	..	1/8	7/8	18 3/16	1/8	13/16	18 3/8	3/16
5/32	23/32	16 3/16	5/32	21/32	16	3/16	5/32	21/32	16 3/16	5/32	5/8	16¼	1/16
3/16	9/16	14⅛	3/16	17/32	13 7/8	1/4	3/16	1/2	14 1/16	3/16	1/2	14	1/16
3/16	7/16	12¼	3/16	7/16	11 7/8	3/8	3/16	13/32	11 13/16	3/16	13/32	11¾	1/16
7/32	11/32	10⅛	7/32	11/32	9 15/16	3/16	7/32	11/32	9 11/16	7/32	11/32	9⅝	1/16
7/32	5/16	8 5/16	9/32	9/32	7 7/8	7/16	7/32	9/32	7 13/16	7/32	9/32	7 9/16	1/4

The following are the particulars of Rogers' Locomotive Works Link-Motion:

Diameter of cylinder		16	inches.
Length of stroke		22	"
Steam ports	14 ins. ×	1¼	"
Exhaust ports	14 " ×	2½	"
Outside lap of valve, each end		11-16	"
Inside lap on each side		⅛	"
Throw of eccentrics		5	"
Horizontal distance centre of axle to centre of rocker	6 ft.	5	"
Centre of rocker above cent. line of engine		7½	"
Length of rocker arms		7¾	"
Radius of centre of link	5 ft.	11½	"
Length of eccentric rod, from centre to eccentric strap to centre of knuckle-joint, 6 ft. 3⅛ ins.; knuckle-joint 2½ ins. back of centre of link, making whole distance from centre of strap to centre line of slot of link, 6 ft. 5⅝ ins., or 6⅛ ins. more than radius of centre of link.			
Centres of knuckle-joints apart		13	"
Size of slot in link	17 ins. ×	2¼	"
Centre of stud on saddle is in centre of the *length* of the link, and ¼ inch behind the centre of the slot, or ¼ inch towards knuckle-joints.			
Horizontal distance of lifting shaft, front of centre line of axle	4 ft.	9 7-16	"
Centre of lifting shaft below centre line of engine		14¼	"
Length of lifting arms, centre to centre		18	"
" " hanger " "		13	"

It will be seen that the radius of the link is less than the distance from centre of axle to centre of rocker arm stud, at half throw. The peculiarity is to assist in equalizing the cut-off.

The greatest slip of the block, with this link, as given in the working tables of the builders, does not exceed ¼ inch. The link is 1⅞ inches wide on the wearing surface and 1½ inches thick around the slot.

Table of Link-Motion.

No. of Notch.	Per Cent. of Admission.	Travel of Valve.	Lead on Steam Port.	Lead on Exhaust.	Commencement of Expansion.		Opening of Steam Port.		Exhaust Opens.	Exhaust Closes and Compression Begins.
					FRONT.	BACK.	FRONT.	BACK.	FRONT.	
		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		
1	80	$4\frac{1}{2}$	$\frac{1}{16}$	$\frac{5}{8}$	$19\frac{5}{8}$	$19\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$21\frac{1}{2}$	$21\frac{3}{4}$
2	82	$3\frac{1}{2}$	$\frac{3}{32}$	$\frac{21}{32}$	18	$18\frac{3}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$21\frac{1}{4}$	$19\frac{7}{8}$
3	73	$2\frac{7}{8}$	$\frac{1}{8}$	$\frac{11}{16}$	16	$16\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$20\frac{3}{4}$	$18\frac{3}{4}$
4	64	$2\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{4}$	$13\frac{7}{8}$	14	$\frac{9}{16}$	$\frac{5}{8}$	$20\frac{1}{4}$	$17\frac{3}{4}$
5	57	$2\frac{3}{8}$	$\frac{1}{4}$	$\frac{13}{16}$	$12\frac{7}{16}$	$12\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$19\frac{3}{4}$	$16\frac{3}{4}$
6	50	$2\frac{3}{16}$	$\frac{1}{4}$	$\frac{13}{16}$	$11\frac{1}{8}$	$11\frac{1}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$19\frac{1}{4}$	16
7	43	$2\frac{1}{8}$	$\frac{1}{4}$	$\frac{13}{16}$	$9\frac{9}{16}$	$9\frac{7}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$18\frac{3}{4}$	$14\frac{7}{8}$
8	36	2	$\frac{1}{4}$	$\frac{13}{16}$	8	$7\frac{7}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$17\frac{3}{4}$	$13\frac{1}{2}$

Cause of Variation of Lead in a Shifting Link-Motion.

With a shifting link-motion, the lead varies in raising and lowering the link, for the reason that the eccentric rods sweep from different centres, describing curves eccentric to that which would be made by sweeping from the centre of the axle. The eccentric rods rise and fall on two different centres, similar to the links of a parallel ruler.

Richmond Iron.

To Find the Position of Eccentric.

The angle included between the centre line of the eccentric and that of the crank-arm (for a direct-acting valve motion) may be determined as follows:

1*st*. Locate the crank-pin on either "dead centre," and draw the centre line of the crank-arm.

2*d*. Describe around the centre of crank-shaft a circle equal in diameter to the travel of the slide-vale.

3*d*. Lay off from the centre of this circle (on that part of the centre line which is opposite to the crank-pin) a distance equal to the "lap" of the valve, plus the "lead."

4*th*. Erect a perpendicular line, and produce until it intersects the circle.

5*th*. Lines joining the centre of the circle with the two points thus determined, will form with the centre line of crank-arm, the required angles of eccentric for either forward or reverse motion.

The eccentric was invented by Mr. Murdock in 1800. Link motion was an improvement on Gray's plan of the variation of travel to produce expansion. The link was invented by Mr. Williams, and was applied to engines of Robert Stephenson in 1843.

Method of Setting the Valves of a Locomotive.

It is supposed that the locomotive is in process of erection. The engineer in charge first locates the cylinder and steam chests, places the valves on their seats, attached to their yokes and stems. The drivers and axles (eccentric pulleys being on) are fitted to their boxes. Guide-rods, one cross-head and connecting rod, tumbling shaft and springs, rocker boxes and rockers, located as per plan. The links, with saddles attached, are swung from the tumbling shaft by their suspending links. The link blocks are then fastened to their respective rockers.

The engineer having attached the stub ends of the eccentric rods to the eccentric straps, prepares a trammel of the requisite length of the rods, and centre punches points, to indicate for the smith the proper length the rods should be pieced out to. They are subsequently put in place. The reversing lever is mounted as well as the unslotted arches. The tumbling shaft is ready for its connecting rod, to form its attachment to the reversing lever. This rod is pieced out to the length indicated by dropping the link into extreme gear, and observing how far over the reversing lever is capable of motion.

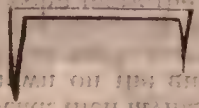
There is no occasion to introduce the pistons and their rods, but simply to take all dimensions which have reference to their motions from centre punch marks on the cross-head. The engine is then jacked up, under the driving boxes, so that the drivers clear the track.

The first step in the process of alignment is to mark the quadrant points on the driver, with reference to an arm clamped on the main frame of the engine, which arm will so overlap the face of the driver that the passage of the points during the revolution of the wheel will be noted very distinctly.

The driver is now connected with the cross-head; it is revolved until the latter reaches the end of its stroke, and this extreme point is marked on the guide-rods; distant from this point, about 2 inches along the guide-rods, another centre punch mark is made. After revolving the drivers, their motion is arrested when the end of the cross-head arrives at this second point; while stationary, the scriber is drawn along the overlapping arm, and a line is marked on the face of the driver. Upon revolving the drivers their motion is arrested when the points a second time are in alignment, and the face of the wheel is scribed as before. We thus have two relative points on the face of the wheel equally distant from the relative point when the crank-pin is on the centre; therefore the bi-section of this arc gives us a point which, being placed immediately under the scribing edge of the overlapping arm, will place the crank-pin on the centre. By repeating this process, with the cross-head at the end of the guide-rods, we are able accurately to find the other "centre." Thus obtaining the centres on the face of the driver, we can readily tram the quadrants.

The strap of the connecting rod is next removed, and the rod allowed to rest on its yoke. With these four points carefully determined, we are able, at any moment, to pinch the crank-pin of either cylinder over to its centre.

The eccentric pulleys are then placed, with nearly the proper amount of lead (as nearly as the eye can judge), the reversing lever thrown into full gear forward, and the drivers pinched over until one of the crank-pins is on its centre. It should here be observed that, instead of measuring the lead directly from the valve and the edge of its port, with the steam chest bonnet off, it is customary, after the valve is scraped to its seat—*1st*, To place it so that on one side the steam port is just closed, and having made a centre punch-hole on the face of the stuffing box-flange, to place the small leg of the valve-gauge into it; with the other leg scribe a line on the valve stem, on which make another centre punch-hole; *2d*, Place the valve until the opposite port is just closed, and mark a second centre punch-hole on the valve-stem, as will be indicated by the valve-gauge. This gauge is made of a small piece of steel, bent thus:



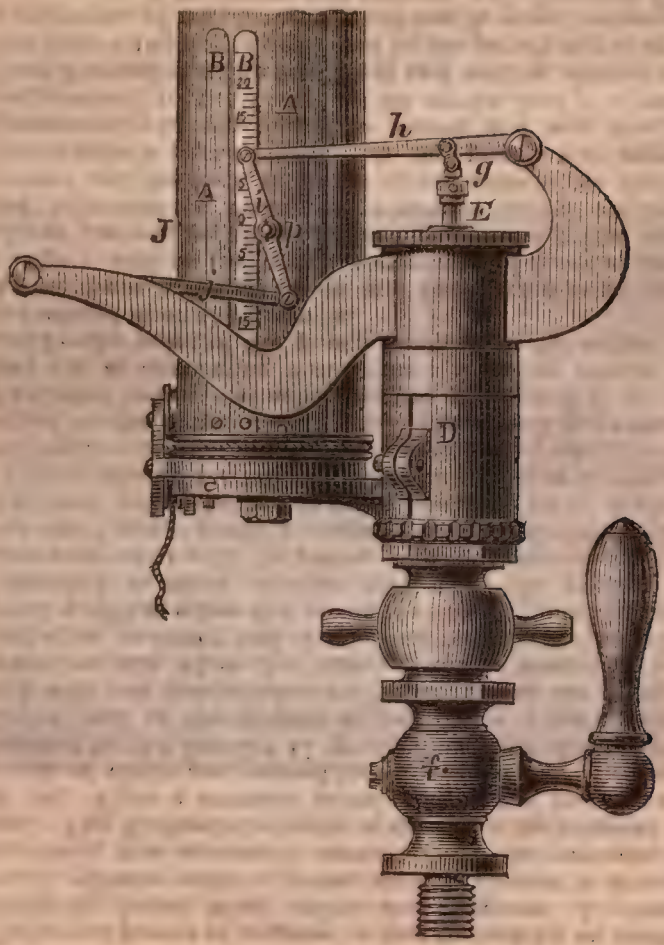
and sharply pointed on the legs. One of these should accompany each engine. It is thus apparent that the engineer can, in case of the eccentric pulley slipping, readjust the valve with the proper lead, without removing the steam-chest bonnet. The lead the valve now has, is noted in the forward and the back stroke, if not equal, is made so by turning the right and left nut on the valve stems, and then locking the check-nuts. The forward eccentric pulley is then altered until it gives the required lead. This operation is performed on both sides of the engine, until a perfectly square motion is obtained in forward gear. After this, the point at which the reversing lever lock-catch strikes the arches is carefully marked with a scriber, and the lever is thrown into full gear back. If on trial it appears that the motion is not a square one, it will be necessary to introduce a slip of sheet iron or tin between the head of the

backing eccentric rod and the eccentric strap, then draw the bolts tightly together. This slip should just equal in thickness half the difference between the leads. After this adjustment results in a square motion, the backing eccentric should be altered until the same lead is produced in full gear back, as was given in full gear forward. Having repeated this process on both valves, the arches should be marked. In order to insure perfect accuracy the lead and squareness of the valve in forward motion should be examined, to guard against any disarrangement which may have occurred while adjusting the valve motion. It now remains to mark the other notches. These for a 24-inch cylinder are usually 8, 10, 12, 16, 22, and indicate the points of cut-off when the reversing lever is in either notch. They may be accurately described by again attaching the connecting-rod to the driver and cross-head, then laying off the points from the end of the stroke as shown on the guides, pinching over the driver until the cross-head mark corresponds with either of these, and drawing back the reversing lever until the valve just closes the port. At this point mark the arches, and so continue to procure the other points. The centre notch would be found at the point of bi-section of the arches between the two points of shortest cut-off.

The second method, or that of approximation, consists in pinching over the driver from one of the centres to the quadrant points, then draw the reversing lever back until the valve just closes and scribe the arches. This gives the half-stroke mark approximately in both motions. Mark the centre notch after having brought the link block directly under the centre of the saddle. It only remains to attach the eccentric pulleys to the driving axle. This is done by scribing the position of the feather on the pulley ribs and the axle, then sinking a ⅝-in. feather ¼ in. into axle, ⅜ inch into the pulley, driving it in solid, also letting the points of two steel ¾-inch set-screws into the axle, through each pulley. The arches are then removed, slotted, and case-hardened. The process of setting the valves of an engine already constructed is effected in like manner.

THE RICHARDS INDICATOR.

And How to Use It.



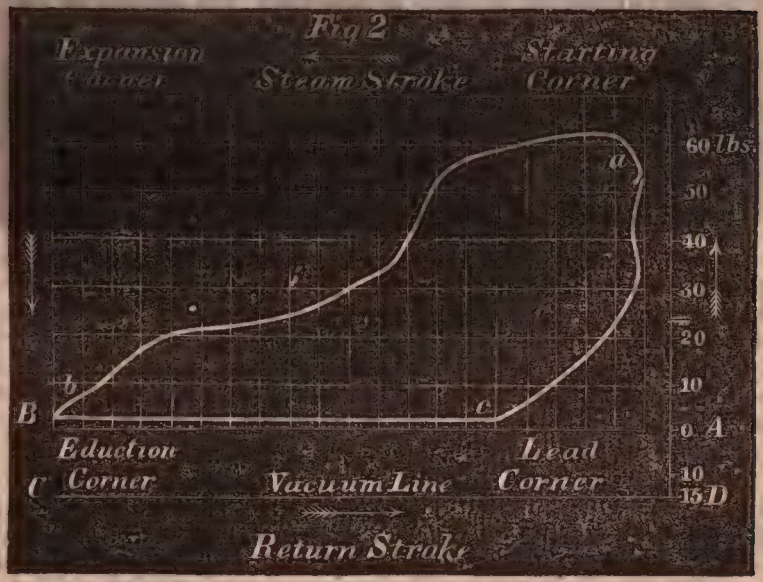
Ramapo Wheel and Foundry Co.

The actual power of engines is ascertained by an instrument invented by James Watt, called the indicator. It consists of a small cylinder with a piston moving against a spring, and compressing it to an extent answerable to the pressure of the steam. The Richards indicator is shown in the annexed figure, page 129. Upon a movable barrel A a piece of paper is wound, the ends of which are secured by the clamps B. The barrel is supported by the bracket C, proceeding from the body of the indicator, and at the bottom of the barrel a watch-spring is coiled, with one end attached to the barrel and the other to the bracket, so that when the barrel is drawn round by a string wound upon its lower end, the spring returns the barrel to its original position when the string is relaxed. The string must be attached to some suitable portion of the engine, giving motion coincident with the piston. In the inside of the cylinder D is a small piston moving steam-tight in a cylinder of which E is the piston rod; attached to it is a spiral spring of steel, which the piston, when forced upwards by the steam, or drawn downwards by the vacuum, either compresses or extends; *f* is a cock attached to the cylinder of the indicator, which is screwed into the cylinder cover. Attached to the piston-rod E, at *g*, is a radius bar *h*, connecting with arms *i j*, giving motion to the pencil P—the point of the pencil bears upon the surface of the paper wound upon the drum A.

As the drum A rotates round and back again every stroke of the engine, and as the pencil moves up and down again every stroke of the engine, the combined movement traces upon the paper a species of rectangle, which is called an indicator diagram; and the form of this diagram determines the nature of the engine's performance. If the pencil was moved up instantaneously to the top of its stroke, and was also moved instantaneously to the bottom of its stroke, and if it remained without fluctuation while at the top and bottom, during rotation of the barrel, the figure described by the pencil would be a perfect rectangle, of which the vertical length would represent the total pressure of the steam and vacuum, and therefore the total pressure urging the piston of the engine. But in practice the pencil will neither rise nor fall instantaneously, nor remain at a uniform height throughout the stroke. If the steam be worked expansively, the pressure will begin to fall as soon as the steam

is cut off, and at the end of the stroke, when the steam comes to be discharged, the subsidence of pressure will not be instantaneous, but will occupy an appreciable time. Therefore, in no engine can the diagram be a perfect rectangle; but the more nearly it approaches a rectangle the larger will be the power produced at every stroke with any given pressure, and the area of the space included within the diagram will in every case accurately represent the power of the engine exerted during that stroke.

Thus in the annexed diagram, Fig. 2, the atmospheric line A B, described by the pencil without steam, is equivalent to

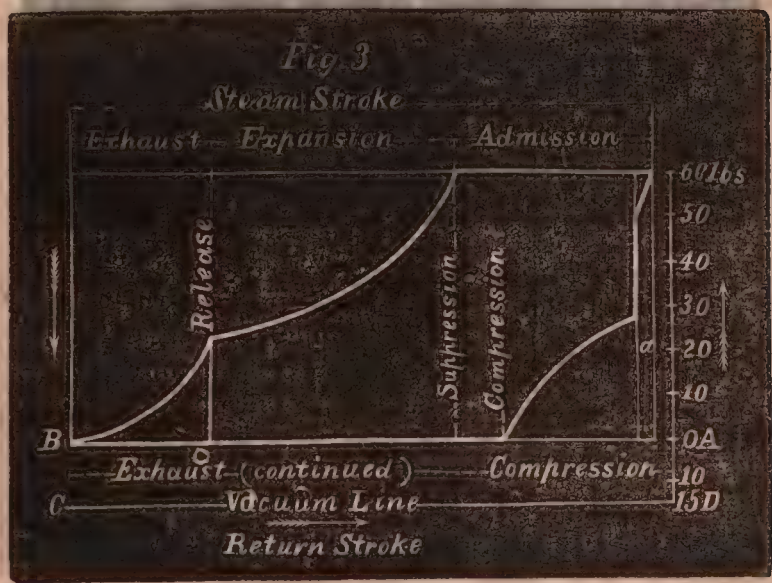


the stroke of the piston, which may be divided into as many aliquot parts as there are inches in the stroke of the piston. Perpendiculars raised on this line will cut the diagram at points indicating the corresponding pressure. The curved line *a b* traced by the pencil exhibits the varying pressure of the steam

during the steam stroke; in the direction A B, and during the return stroke B A, the continuation *b c a* represents similarly the back pressure due to incomplete exhaust. The curve is thus arranged to begin and end in itself, and it plainly represents the pressure of the steam on one side of the piston during a double stroke. Divide the base line into inches of stroke, say 20, and at each division draw vertical lines; similarly draw lines parallel to the atmospheric line at equal distances of say 10 lbs. pressure by the indicator scale, the force of steam at all points of the stroke will be obvious.

How to Take an Indicator Card.

Having adjusted the cock of the indicator to the cylinder head, and arranged the cord to give the motion of the engine—1*st*, Fasten paper on which card is to be taken to the cylinder A, by the clamps B, open the cock *f*, and allow the piston to move up and down, to see that all is right; then shut the cock, bend the pencil to the paper, and it will trace the atmospheric line A B, Fig. 3 (of the diagram taken from the cylinder of a



locomotive); then with the hand depress the piston until the index is 15 below O on the scale of pounds, and it will trace line C D, representing a perfect vacuum. The piston is represented as starting from the upper right-hand corner, under a pressure of 60 lbs., until it reaches the point of cut-off or suppression. The admission being stopped, the expansion of the steam that has been admitted and now confined commences, and is indicated by the fall in the curve, showing a reduction of the pressure as the piston moves on. The progressive reduction of the pressure during the period of expansion is shown by the continual depression of the curve, which continues until the piston reaches the point of release; at this point a second change takes place, and the piston enters its last stage of progress toward the end of the steam stroke. The period of exhaust commences while the piston is short of the end of the stroke; the curve breaks away almost vertically toward the point B, and shows that at the instant of release the steam which was primarily admitted at 61 pounds pressure, has fallen to 23 pounds pressure previously to its being released, quickly discharges itself, in virtue of its remaining elasticity, and is entirely evacuted before the piston has finished the stroke, as shown by its merging the curve in the datum line. But though the indicated pressure of the steam is nothing at this point, being reduced to an equality with that of the atmosphere, still it has the pressure of one atmosphere, or 15 pounds absolute pressure, and there exists a cylinder full of this steam behind the piston at the end of the steam stroke; so the duties of the exhaust are by no means completed. The exhaust port should be kept continuously open to the face of the piston we have been following, throughout the whole of the return stroke; and this is shown by the diagram, by the exhaust continuing during its progress at the zero point, insensible to the indicator, until the instant of closing the valve or compression, when, being no exit for the exhaust steam before the advancing piston, the diagram line starts up toward the right hand; the steam finding no way of escape is compressed against the end of the cylinder, into a space which continually grows less as the piston advances. While the volume of the steam is being thus forcibly reduced, its density is increased, its pressure is raised in proportion, and the accumula-

tion of back pressure so induced is promoted until near the end of the return stroke, when it becomes lost in the superior pressure of the steam admitted by anticipation of the business of the next steam stroke. The critical point at which this interruption occurs is shown by the small compartment *a* in the diagram, representing the period of pre-admission. The curve then starts vertically upward at the instant the valve opens the steam port to the steam chest, and reaches the initial pressure of 61 lbs. for the commencement of the next steam stroke.

In this diagram all the points of distribution are fully defined. The period of admission is about one-third of the whole stroke, that of expansion something more; the diagram showing that one-half of the work of the steam is performed while shut up in the cylinder.

The exhaust supplies its quota of effect, inasmuch as the evacuation is a work of time, and the extra positive pressure so yielded is represented by the small triangular space between the point of release and the end of the stroke.

If the corner marked expansion corner, Fig. 2, is much cut away, the engine is working to a proportionate extent expansively.

If the eduction corners are much cut away or slanted, the exhaust passages are too small.

If the lead corner is much slanted off, then the lead given to the engine is great; the steam side of the valve is opened before the end of the stroke, or the exhaust passage is shut too soon, which causes compression.

In some cases the vapor may be compressed beyond the pressure of the steam, and cause the line of the diagram to form a loop above the steam line at the "starting corner."

If the starting corner is slanted much, then the steam is not admitted sufficiently early.

Every change in the engine which diminishes the area of the diagram, by the rounding of its corners, diminishes the power of every stroke, for the space enclosed in the pencil line exactly represents the power of a stroke of the engine (with the exception of the rounding of the lead corner, lead being efficacious in the working of the engine).

While expansion diminishes the power of each stroke, the reduced power of the engine is more than compensated by the saving in the steam consumed.

To compute the power of the diagram, set down the length of the spaces formed by the vertical lines from the base, in measurements of a scale accompanying the indicator, and on which a tenth of an inch usually represents a pound of pressure; add up the total length of all the spaces, and divide by the number of spaces which will give the mean length, or the mean pressure upon the piston in pounds per square inch; multiply the area of the piston in square inches by the pressure in pounds per square inch, and by the speed of the piston in feet per minute, and divide by 33,000, which gives the actual number of horses power.

For full detailed working of the Indicator, see D. K. Clarke's work on Railway Machinery; also Richards' Steam-Engine Indicator, by Charles T. Porter.

By the indicator alone can the locomotive superintendent know the working of his engines, the distribution of the steam in the cylinders, their defects and probable cause of the same; give new interests in the investigations of the action of steam, and if correctly studied, much economy in the working of his engines.

FRICTION.

M. Morin, under the sanction of the French Government, in the years 1831, 1832, and 1833, made a very extensive set of experiments to determine, if possible, the laws of friction, by which the following were fully established:

1*st*. When no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) *is directly proportional to the force with which they are pressed perpendicularly together;* so that for any two given surfaces of contact, there is a constant ratio of the friction to the perpendicular pressure of the one surface upon the other. While this ratio is the same for the same surfaces of contact, it is different for different surfaces of contact. The particular value of it in respect to any two given surfaces of contact is called the co-efficient of friction, in respect to those surfaces.

2d. When no unguent is interposed, the amount of friction is in every case *wholly independent of the extent of the surfaces of contact; so that the force with which two surfaces are pressed together being the same, their friction is the same, whatever be their surfaces of contact.*

3d. That the friction of motion is wholly independent of the velocity of the motion.

4th. That where unguents are interposed, the co-efficient of friction depends upon the nature of the unguent, and upon the greater or less abundance of the supply.

Co-efficients of Friction in Axles.

Axle.	Bearing.	Dry.	Greasy and Wetted.	Ordinary lubrication.	Lubricated continuously.	Pure carriage grease.	Lard and plumbago.	Fatty matter.
Bell metal	Bell metal ...	..	..	.097	..	..	..	..
Cast-iron	" ...	..	..	..	.049	..	..	..
Wrought-iron.	" ...	.25	.19	.07	.05	.09	.11	..
" " .	Cast-iron	..	..	.07	.05	..	..	..
Cast-iron	"	..	.13	.07	.05	..	..	0.13
"	Bell metal ...	.19	.16	.07	.05	.06	..	.16
Wrought-iron.	Lignum vitæ.	.19	..	.12	..	..	..	..
Cast-iron	" " .	.18	..	.10	.09	..	.11	.14
Lignum vitæ..	Cast-iron	..	..	.11	..	..	..	.15
" " ..	Lignum vitæ.	..	..	..	.07	..	..	..

Steam-Engine Governor.

L = Vertical height from plane of revolution to point of suspension in *inches.*

R = Number of revolutions per *minute.*

$$R = \frac{187.5}{\sqrt{L}} \qquad L = \left(\frac{187.5}{R}\right)^2.$$

Area of Fire Grate.

Equal .0022 multiplied by area of heating surface in square feet, squared, divided by water evaporated in cube feet per hour.

Area of Heating Surface.

Equal 21.2 multiplied by square root of water evaporated in cube feet per hour, multiplied by area of fire grate in square feet.

One cubic foot of water per hour converted into steam equals 1 horse-power.

Grate area of locomotives 6 square feet per square foot fire surface, area of grate 1-80—total heating surface.

Proportion of Boilers—Land.

For each nominal horse-power, a boiler requires—

1 cubic foot of water per hour.
1 square yard of heating surface.
1 square foot of fire grate surface.
1 cube yard capacity.
28 square inches of flue area.
18 square inches of area over bridge-wall.

For cylindrical double-flued boilers, length multiplied by diameter, divided by 6 = nominal horse-power.

Tubular Boilers.

1 cubic foot of water.....	per	horse-power.	
10 square feet heating surface.....	"	"	"
½ square foot fire grate.....	"	"	"
10 square inches sectional area of tube.	"	"	"
13 square inches flue area.....	"	"	"
7 square inches chimney area.....	"	"	"
8 cube feet total boiler capacity.....	"	"	"
2 cube feet steam room.....	"	"	"

Diameter of tubes, 1-30th of their length.

Relative Value of Heating Surface.

Horizontal surface above the flame = 1.00.
Vertical = .50.
Tubes and flues = 1¼ of their diameter.
Convex surfaces above the flame = 1⅙ diameter.

Power Required to Punch Boiler Plates, in Tons.

Multiply diameter of hole in inches, by thickness of plate in inches, the sum multiplied by 80, equal power required in tons.

RULES FOR THE STRENGTH OF BOILERS.

For the cylindrical parts—To find the working steam pressure due to a given diameter, thickness of plate, and quality of of joint: *Rule*—Multiply thickness of plate in inches by 2, and by the working strength of the longitudinal joint in lbs. per square inch, and divide by the diameter in inches; quotient is working steam-pressure in lbs. per square inch.

For Strength of Plates and Joints, see page 276.

To Find Thickness of Plate,

Due to a Given Diameter, Quality of Joint, and Working Pressure.

Multiply the working pressure in lbs. per square inch, by the diameter in inches, and divide the product by the working strength of the longitudinal joint in lbs., and by 2. The final quotient is the required thickness of plate in inches.

The ultimate or bursting pressure is five times the working pressure.

To Find Working Steam Pressure,

Due to a given Diameter of Tie-Rod, and Area of Segment to be guarded by it.

Divide the working strength of the tie-rod in lbs., by the area of the segment in square inches; quotient is working steam-pressure in lbs. per square inch.

To Find Thickness of Plates of Stayed Surfaces.

Multiply the square root of the pressure in pounds per square inch, by the greatest distance between the stays in inches, and by .008; product equals thickness of plate in inches.

To Find Area of Segment,

Due to a given Diameter of Tie-Rod and Working Pressure.

Divide the working strength of the tie-rod in lbs. by the working-pressure in lbs. per square inch; quotient is area of segment in square inches.

Working tensile strength of best iron rods is—

⅞-in. diameter...	8,000 lbs.	Deduct 10 per cent. if the rod is reduced by screwing.
1-in. " ...	10,000 "	
1⅛ " ...	13,000 "	

To Find Dimensions of Stay Bolts.

Multiply area supported by stay in square inches by pressure of steam in pounds per square inch; the sum divided by 9,000 equals area of stay bolt in square inches, if the stay is thickened out where the screw is cut. If the screw is cut out of the body of the stay, divide by 6,000. Where stays are secured by keys, the stay at the end should be 1¼ diameter of the body of the stay.

Depth of cutter—1.6 diameter of stay.
Thickness of cutter—0.3 diameter of stay.

To Find Working Strength of a Roof-Stay (or Crown-Bar) of Given Dimensions, fixed in its place.

Multiply thickness of stay at the centre in inches, by the square of its depth at the centre in inches, and by 30; divide the product by the length of the span in inches; quotient is working load in tons equally distributed, when stay is fixed in its place.

Staying Locomotive Boilers.

Fire-box Water Spaces.

Working pressure in lbs. per square inch being ⅙ of bursting pressure; stays, ¾-in. diameter copper plates, ½-in. thick; iron ditto, ⅜-in. thick.

Stay.	Plate.		Stays 5 inches apart.	Stays 4 inches apart.
Copper.	Copper.	Screwed and Riveted.	107	185
Iron.	Copper.	Screwed and Riveted.	160	250
Iron.	Copper.	Screwed only.	120	190
Iron.	Iron.	Screwed and Riveted.	185	290

For low-pressure boilers, at 20 lbs. per square inch, flat portions should be stayed at intervals of 12 inches apart.

To Find the Pressure borne by the Roof-Stays (or Crown-Bars) of a Fire-Box.

Multiply span of the roof in inches, by the pitch of the stays in inches, and by the pressure in lbs. per square inch, and divide by 2240; the product is the pressure uniformly distributed, borne by each roof-stay, in tons.

Strength of Boiler Plates and Joints.

Working strength of best boiler plates are—

Yorkshire plates, per square inch of entire section				..	11,000 lbs.
Staffordshire "	"	"	"	..	9,000 "
American "	"	"	"	..	14,000 "
" ordinary,	"	"	"	..	12,000 "
Cast-steel plates,	"	"	"	..	18,000 "

WORKING STRENGTH OF JOINTS, PER SQUARE INCH OF ENTIRE SECTION.

	Best Yorkshire.	Best Staffordshire.	Best American.
Scarf welded, joint.....	11,000	9,000	14,500
Double riveted, double welt.	9,000	7,000	10,500
" " lap joint....	8,000	6,500	9,750
Lap, welded joint.....	7,400	6,000	9,000
Double riveted, single welt..	7.300	6,000	9,000
Single riveted lap.....	6,700	5,400	7,800

The strain per unit of length upon transverse circular joints is only half of that on longitudinal joints; longitudinal seams should therefore be the strongest, and the double riveted, double welt joints should be used for longitudinal joints, and the single riveted lap joints for circular seams.

RIVETING FOR BOILERS.

Table of Dimensions of Rivets, etc., for Steam Boilers.

Thickness of Plate.	Diameter of Rivet.	Length of Rivet from Head.	Distance apart of Rivets, Centre to Centre.	Breadth of Lap, Single Riveting.
in.	in.	in.	in.	in.
3-16	3/8	7/8	1 1/4	1 1/4
1/4	1/2	1 1/8	1 1/2	1 1/2
5-16	5/8	1 3/8	1 5/8	1 7/8
3/8	3/4	1 5/8	1 3/4	2
1/2	13-16	2 1/4	2	2 1/4
5/8	15-16	2 3/4	2 1/2	2 3/4
3/4	1 1/8	3 1/4	3	3 1/4

For double-riveted joints add 2/3ds of the breadth of lap.

Ramapo Wheel and Foundry Co.

Bridge Riveting.

In boiler-plate bridges the plates are from ¼ to ½ inch thick, with rivets ¾ to 1 inch diameter, and 3 inches apart in the top of the girder, and 4 inches apart in the bottom.

Table of the Working Pressure of Locomotive Boilers made of Best American Charcoal Plates.

Inside Diam. of Shell in inches.	Thickness in inches.	Double Riveted double Welt.	Double Riveted Lap.	Single Riveted Lap.
30	1-4	187	166	140
	5-16	235	209	174
	3-8	281	225	209
33	1-4	170	151	127
	5-16	212	189	159
	3-8	255	227	190
36	1-4	156	139	116
	5-16	195	174	145
	3-8	236	209	174
39	1-4	145	128	108
	5-16	181	160	129
	3-8	218	192	161
42	1-4	134	119	100
	5-16	169	148	125
	3-8	201	179	150
45	1-4	125	111	94
	5-16	156	139	117
	3-8	187	166	140

WORKING PRESSURE OF LOCOMOTIVE BOILERS—Continued.

Inside Diam. of Shell in inches.	Thickness in inches.	Double Riveted double Welt.	Double Riveted Lap.	Single Riveted Lap.
48	1-4	117	104	88
	5-16	146	130	110
	3-8	176	156	141
51	1-4	110	98	82
	5-16	137	122	102
	3-8	165	146	122
54	1-4	104	92	77
	5-16	130	115	96
	3-8	156	138	125
57	1-4	99	88	74
	5-16	124	110	92
	3-8	149	132	111
60	1-4	94	83	70
	5-16	118	103	88
	3-8	141	125	105

To find working pressure of ordinary American plate, multiply pressures given in table by..... .88
For cast steel plates..... 1.36

EXPLOSION OF LOCOMOTIVE BOILERS.

The expansion and contraction of the plates at the seams of boilers causes the scale to crack sooner than in the other portions, allowing the iron to be acted upon more rapidly than in those parts which are coated, making grooves in the plate, which soon reduces their thickness; but the most general cause may be summed up in the word NEGLECT.

Thickness of Boiler Iron, and Pressure Allowed by United States Laws.

Pressure equivalent to the Standard for a Boiler 42 inches Diameter and ¼ inch Thick.

Wire Gauge.	Thickness in 16ths.	Diameter in Inches.						
		34 ins.	36 ins.	38 ins.	40 ins.	42 ins.	44 ins.	46 ins.
No.		Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.	Lbs.
1	5	169.9	160.4	152.	144.4	137.5	131.2	125.5
2	4½	158.5	149.7	141.8	134.7	128.3	122.5	117.2
3	4¼	147.2	139.1	131.8	125.1	119.2	113.7	108.8
4	4	135.9	128.3	121.6	115.5	110	105.	100.4
5	3⅔	124.5	117.6	111.4	105.9	100.8	96.2	92.1
6	3⅓	113.2	106.9	101.3	96.2	91.7	87.5	83.7
7	3	101.9	96.2	91.2	86.6	82.5	78.7	75.3

Notes on Strength of Boilers.

Boiler Plates and Bolts.—The tensile strength of iron plates and bolts ranges from 42,500 to 62,000 lbs. Mean tensile strength of copper plates, 33,000 lbs. up to 120°; temperature at 222° = 32,000 lbs.; at 550° = 25,000 lbs.

Bursting or Collapsing Pressures.—Iron plates should be based upon a strength 2-5 that of ultimate strength of the metal; for use in salt water, at ½ that of its ultimate strength.

Resistance to collapse much less than to bursting.

Strength of Stay Bolts—Of iron, for use in salt water, should be taken at 1-7; fresh water, 1-6; copper, 1-5 of ultimate tensile strength.

Stay-bolts, when screwed and riveted, are ⅓ stronger than when screwed alone.

Relative Strength of Riveted Joints per Square Inch of Single Plate.—Single-lapped, *machine riveted*, rivets 3 diameters, centre to centre, 25,000 lbs.; *hand riveted*, 24,000 lbs.; *staggered riveting*, and equidistant from centres, 30,500 lbs.; *abut joints*, hand riveted—rivets not "*staggered*," and equidistant from centres—single cover or strip, 30,000 lbs.; rivets set "*square*," single cover or strip, 42,000 lbs.; double covers or strips, 55,000 lbs.

To find Requisite Quantity of Water for a Boiler.

Add 15 to the pressure of steam per square inch, divide sum by 18, multiply quotient by .24; product is quantity in U. S. gallons per minute for each horse-power.

To find Height of a Column of Water,

To Supply a Steam Boiler against any Pressure of Steam required.

Multiply pressure in pounds upon a square inch of boiler by 2.5; product will be height in feet above the surface of the water in boiler.

Cold Water and Feed Pumps.

The cold-water pump usually = diameter of cylinder × 0.3 when stroke = ½ stroke of engine.

The cold-water pump usually = diameter of cylinder × 0.42 when stroke = ¼ stroke of engine.

Velocity of water in pump passages should not exceed 500 feet per minute. Pump valves should not be of less area than ¼ area of the pump.

Feed Pumps for High-Pressure Engines.

Diameter = 1.11 diameter of cylinder when pump's stroke = stroke of the engine.

Diameter = ⅛ diameter of cylinder when ½ stroke of the engine.

Diameter = ⅙ diameter of cylinder when ¼ stroke of the engine.

Feed Pumps for Condensing Engines.

Diameter = 1.11 diameter of cylinder when ½ stroke of the engine.

Diameter = ⅛ diameter of cylinder when ¼ stroke of the engine.

EXTRACTS COMPILED FROM U. S. LAWS, RELATING TO STEAMBOAT BOILERS.

Acts of August 30, 1852, *July* 25, 1866, *and Laws of State of New York, June* 22, 1867, *Chap.* 969.

Testing Boilers.

All steam boilers to be tested before used, and annually thereafter, by hydrostatic pressure, limit not to exceed 165 lbs. to the square inch for high-pressure boilers; the limit may be proscribed by the owner. Inspectors shall satisfy themselves by trials that the boilers are well made of good and suitable material; that the openings for the passage of water and steam, respectively, and all pipes and tubes exposed to heat, are of proper dimensions and free from obstruction; that the spaces between the flues are sufficient.

When boilers are supplied by a water connecting pipe through which water may pass from one boiler to another, there shall be provided a similar steam connection, having an area of opening into each boiler of at least one square inch for every two square feet of effective heating surface contained in any one of the boilers so connected, half the flue and all other surfaces being computed as effective. No boiler allowed a greater working pressure than 150 lbs. to the square inch.

Fusible Plugs.

That in or upon the outside flue of each outside high-pressure boiler, there be placed alloyed metals, fusible by the heat of the boiler when raised to the highest working pressure allowed, and that in and upon the top of the flues of all other high-pressure boilers in the steamer such alloyed metals are placed, as aforesaid, fusing at 10 lbs. greater pressure than said metals on the outside boilers, thereby, in each case, letting steam escape.

Pressure Allowed.

That in testing boilers by the hydrostatic test for high-pressure boilers, inspectors shall assume 110 lbs. to the square inch as the maximum allowable pressure on a new boiler 42 ins. in diameter, made of iron plates ¼ in. thick, of best quality, and shall rate working power of all other boilers, whether of less or greater diameter, old or new, according to their strength compared with this standard, and in all cases the test applied shall exceed the working power allowed in the ratio of 165 to 110, and no high-pressure boilers hereafter made shall exceed this standard.

Low-Pressure Boilers.—Allowance for working power for each new boiler, a pressure of only three-fourths the number of pounds to the square inch to which it shall have been subjected by the hydrostatic test, and found to be sufficient therefor, using the water in such tests at a temperature not exceeding 60° Fahrenheit.

No boiler or pipe shall be approved which is made in whole or in part of bad material, unsafe in form, or dangerous from any cause.

Thickness of Iron.

No boiler to which heat is applied on the outside of the shell, shall be constructed of plates of *more* than three-tenths of an inch in thickness, the ends or heads only excepted; shall have not less than 3 ins. of clear space for water between and around their internal flues. When four or more boilers are used in a battery, shall be divided, so that one-half of the boilers employed will act independently of the other half, so far as relates to the water connection.

Safety-Valves.

That safety-valves are of suitable dimensions, sufficient in number, well arranged, and in good working order; that there are a suitable number of gauge-cocks properly inserted, a suitable water gauge and steam gauge.

One or more additional safety-valves (lock-up valves) shall be placed on the boiler of every steamer, and shall be loaded to a pressure not exceeding two pounds above the working steam pressure allowed, and the alloyed metals now required by law to be placed in and upon the flues of boilers shall be fusible, as now required by law, at a temperature not exceeding 445° Fahrenheit.

New York State Law, Chapter 969.

Every owner of a steam boiler shall annually report to the deputy inspector of the Congressional district where boiler is situated, the location of same; and said deputy inspector shall proceed to inspect such steam boiler or boilers, and all appurtenances and appliances connected therewith, and the strength and security of each boiler shall be tested by hydrostatic pressure; and every boiler or boilers so tested shall have, under the control of the inspector-in-chief, such attachments, apparatus, and appliances as may be necessary for the limitation of pressure, locked and secured in like manner as now in practical use by the United States inspectors of steam boilers, according to act of Congress, July 25, 1866. Inspector shall limit pressure to be applied to said boiler, and pressure under which it can be worked, to the owner and engineer.

Every boiler to have a lock-up safety-valve, a high and low-water indicator, with an alarm whistle, so constructed and arranged that the whistle will give an alarm at low-water and at high-pressure of steam, under penalty of $500.

Use of greater pressure of steam than allowed by certificate, $1,000.

Act shall not apply to locomotives or boilers for heating private dwellings.

To find the Ultimate Bursting Resistance of the Shell of a Boiler.

Rule—Multiply double the strain allowed by the tensile resistance of the material allowing for diminution in strength from riveti g) by the thickness of the boiler plate; divide the product by the diameter of the boiler —all in inches. *A safe allowance for the strength of iron is* 5,000 *lbs. per sq. in*

To find the Thickness for a given Pressure.

Rule—Multiply the diameter of the boiler, in ins., by the given working pressure, in lbs., per sq in.; then the 4 right hand figures of the product will represent the proper thickness of the boiler plate, in decimals of an inch.

Ex.—Diameter of boiler = 108 ins.; pressure = 35 lbs. 108 × 35 = 0.3780 ins.—the required thickness.

Comparison between the Resistance to External and Internal Pressure in Wrought-Iron Single-Riveted Flues.

Diameter.	Thickness.	Length.	External Pressure per sq. in.	Internal Pressure per sq. in.	Ratio.
Ins.	Ins.	Ft.	Lbs.	Lbs.	
6	.15	10	205	1,375	1 to 6.7
13	.2	15	163	917	1 to 5.6
18	.25	20	135	764	1 to 5.6

Experiments made by Horatio Allen, Esq., with boiler of U. S. Expansion Experiments, to ascertain proper area of discharge orifice to allow steam to escape at different pressures, and beyond which the pressure would not rise, the orifice being open. Boiler had 20 square feet grate surface, 540 square feet heating surface, and was burning about 12 pounds of coal per square foot of grate.

Pressure, in lbs., above Atmosphere	Size of Orifice, in inches.	Area of Orifice, in sq. ins.	Pressure, in lbs., above Atmosphere	Size of Orifice, in inches.	Area of Orifice, in sq. ins.
1½	3 x 2	6.00	30	3 x 7-16	1.31
5	3 x 1¾	5.25	37	3 x ⅜	1.12
7	3 x 1½	4.50	46	3 x 5-16	.93
8	3 x 1¼	3.75	54	3 x ¼	75
10	3 x ⅞	2.62	67	3 x 3-16	.56
16	3 x ⅝	1.87	93	3 x ⅛	.37
20	3 x ½	1.50	100	3 x 3.32	.28

Deduced from above will be—

Formula.—Let p equal difference in pressure on two sides of orifice, then the area of orifice required per square foot heating surface in boiler (using whole circumference of tubes) = $\frac{1}{13.5\sqrt{(p \times 3)}}$

SAFETY VALVES.

To find Area in Square Inches.

Multiply area of fire-grate in square feet by .8.

Mitre of safety valves should not exceed 1-16 inch in width. The actual area of a safety valve, with a conical seat, equals the sum of the area of the largest and smallest diameters of the conical frustrum, divided by 2.1.

To find Pressure per Square Inch,
Due to the Weight of Lever of Safety Valve.

Multiply distance of centre of gravity of lever from fulcrum, by weight of lever. This sum, divided by area of valve in inches, multiplied by distance from fulcrum to centre of valve, equals weight of lever, per square inch on valve.

To find Pressure per Square Inch,
Due to the Weight of the Valve.

Divide weight of the valve by area of valve in square inches.

To find Weight Required for a Safety Valve, Pressure, Position of Weight, and Position of Valve and Fulcrum being given.

Rule.—From the required pressure on the valve in lbs. subtract weight of the valve, plus the effective weight of the lever; multiply the remainder by the distance between the fulcrum and the valve, and divide the product by the distance between the fulcrum and the weight—quotient is weight in lbs. required to be placed on lever at that distance.

To find Position at which the Weight of a Safety Valve should be Placed from the Fulcrum, for Blowing Off at a Certain Boiler Pressure.

Rule.—From the products of (area of valve, multiplied by pressure per square inch in boiler in lbs., multiplied by the distance of valve from the fulcrum in inches,) subtract the product of (weight of safety valve, with lever in lbs. multiplied by distance of lever's centre of gravity from fulcrum in inches,) and divide the remainder by weight hung on the safety valve lever in lbs. The distance of lever's centre of gravity from fulcrum, may be measured (after balancing lever with valve attached) on a sharp edge.

SCHEDULE OF COMMITTEE OF THE FRANKLIN INSTITUTE,

Giving the least aggregate Area of Safety-Valves (being the least sectional Area for the Discharge of Steam), to be placed upon all Stationary Boilers, with Natural or Chimney Draught.

Formula for area: $A = \frac{22.49}{P + 8.62}$, in which A = area of combined safety-valves, in square inches; G = surface of grate, in square feet; P = pressure of steam, in pounds, per square inch, to be carried in the boiler above the atmosphere.

N. B.—Where boilers have a forced or artificial draft, the combustion of 16 lbs. of coal per hour should be taken as equivalent to the one square foot of grate surface = G in the formula and table.

Where boilers are heated by the waste heat of furnaces, or otherwise than by fire upon grates, the value taken for G must be estimated, by a competent person, based upon the comparative performance of boilers with others heated in the usual way.

TABLE GIVING RESULTS OF THE FORMULA FOR 1 SQUARE FOOT OF GRATE, AS APPLIED TO BOILERS USED AT DIFFERENT PRESSURES.

	Pressure, in Pounds, per Square Inch.										
Pressures	10.	20.	30	40.	50.	60.	70.	80.	90.	100.	120.
	Areas, in Square Ins., corresponding to each Square Ft. of Grate.										
Areas ...	1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0 23	0.21	0.17

Ex.—Suppose boiler to work under pressure of 60 lbs., then each square foot of grate surface should have an area of safety-valve by the table = 0.33 inches. Suppose boiler to have 25 square feet of grate surface, then calculated area for the safety-valves = 8.33 square inches. This would call for two safety-valves, each having an area of 4.16 square inches, or diameter of 2 3-10 inches. If the area given by the formula be applied to the opening of the seat of the safety-valve, the lift of the valve must be at least one-fourth the diameter, to have the same sectional area when open. Hence, should any valves be so constructed that the range of motion will not admit, when fully raised, a lift equal to one-fourth the diameter of the opening of the seat of the valve, the sectional area actually given between the raised valve and the edge of the valve seat should be taken as that to which the rule applies. It is always advisable that the under sides of safety-valve discs should have a globular or pointed form (whether with or without guide wings), and not be made flat, and the dics be bevelled edged, resting upon a narrow bevelled seat, and do not have a flat bearing. Valves, as ordinarily made, after lifting and allowing a flow of steam all around the

disc, do not continue to raise and allow all the steam, as formed, to escape at the constant pressure, but admits some elevation of pressure before opening wide. With the areas given by the formula, and where the discs have been shaped as before described, this increase of pressure will not exceed 10 per cent. of the initial load on the valve, and the additional resistance to opening is a safeguard against the too sudden relief of steam, to the derangement of the water circulation of the boiler, and it should be a legal requirement that every boiler have two safety-valves, the aggregate area of which should be that established by the formula.

To Compute the Pressure of Steam,

When the Height of the Column of Mercury it will Support is given.

Rule—Divide the height of the column of mercury, in inches, by 2,0376; the quotient will give the pressure per square inch, in pounds.

Ex.—The height of a column of mercury is 203.76 inches; what pressure per square inch will it contain? 203.76 divided by 2.0376 = 100 lbs.

To Compute the Temperature of Steam.

Rule—Multiply the 6th root of its force, in inches of mercury, by 177, and subtract 100 from the product; the remainder will give the temperature, in degrees.

N. B.—*To extract the 6th root of a number, ascertain the cube root of its square root.*

To Compute the Pressure of Steam, in Inches of Mercury, Temperature being given.

Rule—Add 100 to the temperature, divide the sum by 177, and the 6th power of the quotient will give the pressure, in inches, of mercury.

N. B.—*To invoke the 6th power of a number, square its cube.*

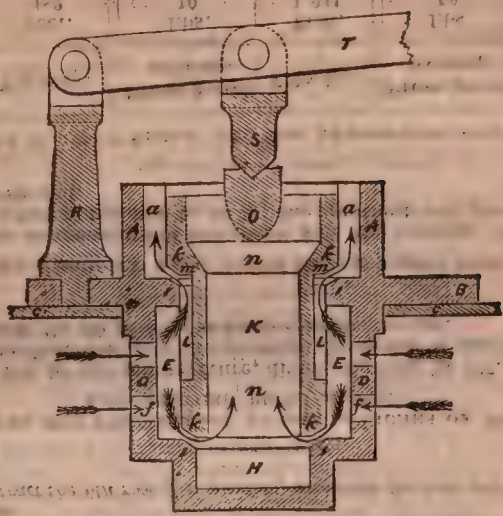
To Compute the Velocity with which Steam flows into a Vacuum.

Rule—To the temperature of the steam add the constant 459, and multiply the square root of the sum by 60.2; the quotient will give the velocity, in feet, per second.

Velocity of Flow of Steam into the Atmosphere per Second.

Press. above Atmosp.	Velocity.	Press. above Atmosp.	Velocity.	Press. above Atmosp.	Velocity.
Lbs.	Feet.	Lbs.	Feet.	Lbs.	Feet.
1	482	10	1,241	50	1,791
3	791	20	1,504	70	1,877
5	972	30	1,643	100	1,957

DOUBLE-SEAT SAFETY-VALVE.



Patented March 10, 1868.

This valve is composed of two cylinders, one within the other, and so placed in relation to the dome or steam space in the boiler, as to project into the steam space, the outer case being fastened to the boiler, and having perforations which admit the steam into an annular chamber between the cylinders, with seats and guides for reception of the inner cylinder, which moves within it, making a double-seat valve; whereby, as the valve is raised from its seats, additional surface is exposed to the steam, which then has a free escape from the boiler, preventing explosion, as the boiler is instantly relieved from pressure.

Its construction is as follows:

A, the outer cylinder, with flange, B, to fasten it on to dome or boiler, C; D, perforated portion of the cylinder, A, inside of boiler, admitting steam to annular chamber, E, through holes, *f f*; G G, projections to guide the valve; K, chamber, elongated

Friction of Plane Surfaces.

Nature of Unguent.

Surfaces.	Dry.	Damp with water.	Olive Oil.	Lard.	Tallow.	Dry Soap.	Polished and greasy.
Wood on wood	.50	.68	..	.21	.19	.36	.35
Metal on metal	.18	..	.12	.10	.11	..	.15
Wood on metal	60	.65	.10	.12	.12	..	.10
Leather on wood or iron	.62	.80	.13	..	..	..	..
Belting on iron pulleys	.54	..	..	..	..	..	..
Belting on wood	.47	..	..	..	..	..	.28

OILS.

Oils are divisible into two great classes—fat or fixed oils, and the essential or volatile oils. The former are usually bland to the taste; the latter, hot and pungent.

When in a solid form are known as fats; when liquid, as oils.

Whether of animal or vegetable origin, they possess the same ultimate constituents—carbon, hydrogen, and generally oxygen, and in nearly the same proportions.

By distillation of vegetable matters and bituminous coal, the elements hydrogen and carbon are made to unite, and to form oils of the carbo-hydrogen and petroleum class

By ultimate analysis, 74 to 80 per cent. carbon; 10 to 13 hydrogen; 9 to 12 oxygen.

The fat oils are mixtures of three substances of similar properties; two of them at ordinary temperature are solid, called stearine and margarine, and the third is a fluid called oleine. The proportion of the latter gives softness and fluidity to the compound.

Summer-strained oil, as compared with winter-strained oil, contains more solid matter and less oil.

In close vessels, oils may be preserved fresh for a long time; but with contact with air undergo progressive changes. Oils which thicken and eventually dry into a transparent flexible substance are said to be drying or siccative, and used for preparations for varnishes and painters' colors. Other oils do not become dry, though they turn thick, become less combustible, and assume an offensive smell; they are then called rancid, and exhibit an acid reaction, which may be removed in a great measure by boiling the oil along with water and a little common magnesia for a quarter of an hour, or until it has lost the property of reddening litmus.

While oils undergo the above change, they absorb a quantity of oxygen equal to several times their volume. To this absorption may be ascribed the raising of the temperature, which happens when wool or hemp, besmeared with oil, is left in a heap, and causes them to ignite.

Oils for Lubrication

Rank in efficiency in following order:

Summer sperm, winter sperm, oil from marrow (for watch springs, etc.), Masons' extra sperm, neat's-foot oil, lard.tallow.

By the test made at Brooklyn Navy Yard by the Navy Department, it was found that no oil or mixture of oils of twenty-four samples presented for testing would lubricate under pressure as well as sperm oils, and that the mixture of oils which would lubricate under pressure contained substances of a gritty nature injurious to the bearings by gradually wearing them out, and the best results were obtained from oils free from mixtures nearest to sperm or lard oils.

Lubricating Qualities are Tested

by allowing a few drops of each class of oil to be placed side by side with pure sperm, on an inclined polished plate of metal, and noting time taken in flowing a given space, also tendency to gum. Or by noting time and force required by a polished slab

of iron to slide down a polished plate, taking some pure oil as a basis for comparison.

Miles Run per Pint of Oil.

Locomotives will average 16 miles to one pint.

Twenty pints of good oil will lubricate eight car journals for a wear of 5,000 miles. Properly constructed boxes and brasses should give a much better result.

Adulteration of Oils and Tests.

In pure sperm oil the oleometer stands at 60; thermometer at 60° Fahrenheit.

Sperm oil is adulterated with other oils, by the use of African fish oil, which is lighter than sperm, and adding other cheaper oils of greater specific gravity, until the whole mixture gives the gravity due to pure sperm.

It may be tested by burning in an oil lamp, by noting tendency to smoke, or crust on the wick, which shows adulteration. A mixture with African oil will smoke.

It may be Tested by Freezing.—If it remains liquid at less than 30° it is not a pure mixture. Freezing will also detect lard or tallow oil in combination with sperm, by freezing in different colored layers.

Adulteration with coal oils by the use of the Pyrometer.

Cotton-seed oil will produce a gum like molasses.

Mixtures of rubber will produce a dark glaze on the journal bearings.

Carbon or petroleum oils, volatilizing by the heat of revolving journals, soon lose their lubricating qualities, and add to the heating they are intended to relieve.

Linseed Oil.

Linseed oil, freshly pressed, has a golden color; turns to a dark brown with age; it has a peculiar smell and disagreeable

taste. Its specific gravity is 0.940; boils at 600° F. Exposed to the air becomes rancid, but on being agitated a short time with warm water and allowed to stand till the two fluids separate, it may be decanted sweet.

A cheap varnish is made by adding litharge and red lead to boiled oil.

Linseed oil is adulterated with common rosin dissolved in it; also with rosin oil, and with various fats and non-drying oils.

The effect is to deteriorate the quality of the oil for painting.

To Detect Rosin or Rosin Oil—Heat a small portion in a porcelain cup, when the peculiar odor of the substance will be noticed, if only 1000th part be present.

To Detect Fats or Non-Drying Oils—Touch the centre of a drop or two of the oil, placed upon a white plate, with a drop of sulphuric acid, conveyed on the end of a glass rod; changes of color are thereby induced, and formations of concentric rings of various shades, which suggest to an experienced eye the nature of the oil and its adulteration.

STEEL SPRINGS.

Rule 1st—To find elasticity of a given steel-plate spring: Breadth of plate in inches multiplied by cube of the thickness in 1-16 inch, and by number of plates; divide cube of span in inches by product so found, and multiply by 1.66. Result, equal elasticity in 1-16th of an inch per ton of load.

Rule 2d—To find span due to a given elasticity, and number and size of plate: Multiply elasticity in sixteenths per ton, by breadth of plate in inches, and divide by cube of the thickness in inches, and by the number of plates; divide by 1.66, and find cube root of the quotient. Result, equal span in inches.

Rule 3d—To find number of plates due to a given elasticity, span, and size of plates: Multiply the cube of the span in inches by 1.66; multiply the elasticity in sixteenths by the breadth of the plate in inches, and by the cube of the thickness in six-

teenths; divide the former product by the latter. The quotient is the number of plates.

Rule 4th—To find working strength of a given steel-plate spring: Multiply the breadth of plate in inches by the square of the thickness in sixteenths, and by the number of plates; multiply also the working span in inches by 11.3; divide the former product by the latter. Result, equal working strength in tons burden.

Rule 5th—To find span due to a given strength and number, and size of plate: Multiply the breadth of plate in inches by the square of the thickness in sixteenths, and by the number of plates; multiply, also, the strength in tons by 11.3, divide the former product by the latter. Result, equal working span in inches.

Rule 6th—To find the number of plates due to a given strength, span, and size of plate: Multiply the strength in tons by span in inches, and divide by 11.3; multiply also the breadth of plate in inches by the square of the thickness in sixteenths; divide the former product by the latter. Result, equal number of plates.

The span is that due to the form of the spring loaded. Extra thick plates must be replaced by an equivalent number of plates of the ruling thickness, before applying the rule. To find this, multiply the number of extra plates by the square of their thickness, and divide by the square of the ruling thickness; conversely, the number of plates of the ruling thickness to be removed for a given number of extra plates, may be found in the same way.

To Test Quality of Steel.

Good tool steel, with a white heat, will fall to pieces; with bright red heat will crumble under the hammer; with middling heat may be drawn to a needle-point.

To test hardening qualities, draw under a low heat to a gradually tapered square point and plunge into cold water; if broken point will scratch glass, the quality is good.

To test tenacity, a hardened piece will be driven into cast-iron by a hardened hammer—if poor, will be crumbled. Excel-

lence will be in proportion to tenacity in hard state. Soft steel of good quality gives a curved line fracture and uniform gray texture. Tool steel should be dull silver color, uniform, entirely free from sparkling particles.

Aquafortis, applied to the surface of steel, produces a black spot; on iron the metal remains clean. The slightest vein of iron or steel can be readily detected by this method.

Rubber Car Springs,

To resist actual compression and bulging, should be used in layers, with intervening division plates; if used in bulk, should have retaining rings to prevent bursting.

The duration of spring depends, of course, on its quality. Pure rubber is of little use; it must be vulcanized. It is adulterated with plumbago, though in best springs as much as 40 per cent. foreign substances are used—principally sulphide of lead and soapstone.

CAR SPRINGS.

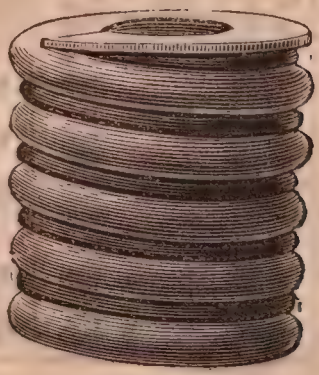
Weight of Rubber car Springs.

Diameter in inches.	Height in inches.	Diameter of hole.	Weight.
4	4	1	3 lbs.
4½	4½	1	4 " 5 oz.
5	5	1	5½ "
5½	5½	1	7 " 10 oz.
6	6	1	9¾ "
6½	6½	1	12 " 5 oz.
7	7	1	15¾ "
7½	7½	1	19½ "
8	8	1	23½ "
8½	8½	1	27¾ "
9	9	1	32¼ "
10	10	1	45½ "
11	11	1	59 "

Car Springs (Steel and Rubber),

As made by the National Spring Company.

Office, No. 1 Barclay Street, N. Y.



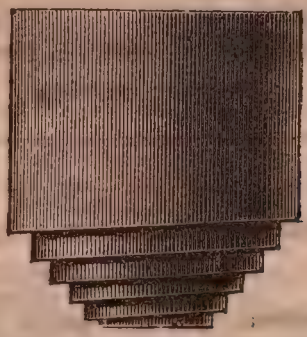
Compound Spiral Spring—for Heavy Freight Work.

A spring six inches in height has a movement of one and a half inches, and is a durable spring.

Size No.	Hole.	Diameter.	Height.	Price.
1	2¼-inch.	5½-inch.	6-inch.	$6 50
2	2¼ "	5½ "	5 "	6 00
3	2¾ "	6 "	5 "	6 50

Volute Spring.

This spring is used extensively for buffers. For journal springs the constant vibration causes the steel to crack sooner or later.



VOLUTE SPRINGS.

Size No.	DIMENSIONS OF SPRING. Hole In.	Diam. In.	Height In.	PRICE.	DESIGNED FOR
1	1	5½	5¾ to 6¼	$6 25	Bearing & Buffer.
1	1½	6	5⅞ " 6⅜	6 50	" "
1	2	6½	5⅞ " 6½	7 25	Jersey "
1½	1¾	6	5¾ " 6¼	6 75	Pennsylvania "
2	1	6	5⅞ " 6½	7 25	Bearing.
3	1	5½	5¼ " 5¾	5 75	"
4	1	5	5¾ " 6¼	5 25	"
4	1½	5¼	5¾ " 6½	5 75	Light Buffer.
4	1¾	6	5¾ " 6½	6 00	" "
5	1	5½	5¾ " 6¾	6 25	Bearing.
6	1	4	5 " 6	4 50	Light Fire Engine.
6	1	4	5 " 6	5 25	Fire Engine.
7	1	5¼	7¾ " 8½	7 25	Illinois Buffer.
7	1½	5	7¾ " 8½	7 25	Erie "
7	1¾	5½	7¾ " 8½	7 25	Ohio "
8	1	5½	4¾ " 5¼	5 25	Bearing.
9	1	5½	6¾ " 7¼	6 75	New York Buffer.
9	1½	5½	6¾ " 7¼	6 75	" " "
9	1¾	5½	6¾ " 7¼	6 75	" " "

The foregoing springs have been before the public for the past ten years, and are conceded to be the best buffer in use; they are durable, elastic, and easily applied.

Rubber Centre Spiral.

This spring is now introduced for the first time. It is believed to be very superior for freight work, having more motion than any steel-coiled spring ever introduced. The gum filling is so placed within the spiral that there can be no abrasion. The steel and gum are both of the very best quality. It is, moreover, the cheapest now in market, costing but $40 per car (eight springs). It is also the lightest in use, weighing but eighty pounds per set.

Car Spring,

As made by Union Car Spring Manufacturing Co., New York.

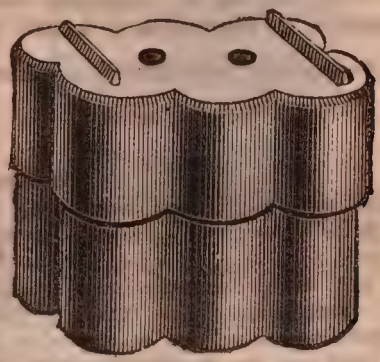
These springs are a combination of a spiral steel spring packed with wool, contained in an iron case, the number of spirals varying with the load to be borne.

A spiral with wool requires 3,500 lbs. to exhaust movement.

A spiral *without* wool requires 1,250 lbs. to exhaust movement.

Each spiral is calculated to carry a load of 625 lbs. for best action.

These springs are made of many patterns. Spirals ready for use are furnished independent of the cases.



N. & A. Middleton's Car Spring

Is similar in form to the Union Car Spring Company's, with the exception that no wool is used in the spirals, and spirals are of iron. They are extensively used for freight cars, and are made in over 100 patterns, to suit all classes of work.

MECHANICS.

Belting.

Horse-power of a belt equals velocity in feet per minute, multiplied by the width—the sum divided by 1,000.

One inch single belt, moving at 1,000 feet per minute = 1 horse-power.

Double belts about 700 feet per minute, per 1 inch width = 1 horse-power.

For double belts of great length, over large pulleys, allow about 500 feet per minute per 1 inch of width per horse-power.

Power should be communicated through the lower running side of a belt; the upper side to carry the slack.

Average breaking weights of a belt, 3-16 × 1 inch wide.

Leather, 530 lbs.; 3-ply rubber, 600 lbs.

The strength of a belt increases directly as its width. The co-efficient of safety for a laced belt is—

Leather = 1-16 breaking weight.
Rubber = ⅛ " "

To find Length of Belting, when Closely Rolled.

The sum of the diameters of the roll and the eye in inches, multiplied by the number of turns made by the belt, and this product multiplied by the decimal .1309, will equal length of the belt in feet.—*Auchinchloss.*

Shafting.

Strength of Wrought-Iron Shafting.—Diameter of shaft in inches equals the cube root of the (nominal horse-powers to be transmitted, divided by the number of revolutions per minute: the quotient multiplied by K .320) = diameter for crank-shafts and prime movers; by K .200 in second motion shafts; by K .100 in ordinary shafting.

Mill-Work.

Diameter and number of Teeth in Driver being given, to find number of Teeth in Driven to give desired Velocity in Driven Wheel.

Rule.—Multiply velocity of the driver by number of teeth it contains, and divide by the velocity of the driven. Quotient will be number of teeth it ought to contain.

Toothed Wheels.

Rules for the Diameter and Pitch.

Pitch and number of teeth given, to find diameter of pitch circle in inches: Multiply the pitch by x multiplier (see Table) of number of teeth.

Diameter of Pitch Circle in inches given, to find the Pitch.—Divide the given diameter by x multiplier (see Table) for number of teeth.

Table of Multipliers.

N.	x.	N.	x.	N.	x.	N.	x.
8	2.6131	32	10.2023	56	17.8308	80	25.4713
9	2.9238	33	10.5224	57	18.1505	81	25.7963
10	3.2360	34	10.8396	58	18.4718	82	26.1096
11	3.5495	35	11.1584	59	18.7893	83	26.4304
12	3.8637	36	11.4737	60	19.1073	84	26.7595
13	4.1789	37	11.7913	61	19.4254	85	27.0645
14	4.4941	38	12.1100	62	19.7431	86	27.3989
15	4 8097	39	12.4240	63	20.0653	87	27.7076
16	5.1258	40	12.7454	64	20.3862	88	28.0238
17	5.4421	41	13.0642	65	20.7050	89	28.3471
18	5.7587	42	13.3838	66	21.0212	90	28.6537
19	6.0757	43	13.6975	67	21.3339	91	28.9923
20	6.3924	44	14.0207	68	21.6561	92	29.3134
21	6.7093	45	14.3355	69	21.9742	93	29.6160
22	7.0268	46	14.6589	70	22.2873	94	29.9515
23	7.3449	47	14.9709	71	22.6094	95	30.2680
24	7.6612	48	15.2897	72	22.9255	96	30.5638
25	7.9787	49	15.6085	73	23.2509	97	30.8931
26	8.2959	50	15.9259	74	23.5695	98	31.2012
27	8.6137	51	16.2491	75	23.8802	99	31.5184
28	8.9318	52	16.5617	76	24.1994	100	31.8362
29	9.2494	53	16.7143	77	24.5273	120	38.2015
30	9.5667	54	17.1984	78	24.8463	150	47.7491
31	9.8842	55	17.5134	79	25.1550		

Proportion of Teeth of Wheels.

From pitch line to top of tooth	= Pitch × 0.33
Total depth of tooth	= Pitch × 0.75
Thickness of tooth on pitch-line	= Pitch × 0.45
Space between teeth on pitch-line	= Pitch × 0.55
Thickness of rim of wheel	= Pitch × 0.45
Thickness of arms, in flat	= Pitch × 2.50
Thickness round centre	= Pitch × 1.3

Mortice wheels to be wider than iron wheels by twice the thickness of the rim; rim to be double the thickness of iron wheels.

Pitches of Equivalent Strength for the Teeth of Wheels in different Materials.

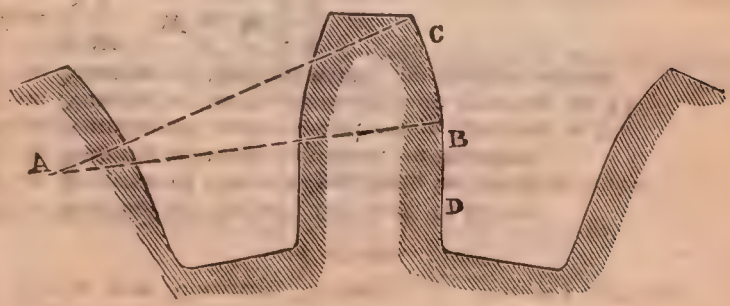
Pitch for cast-iron	= 1.00
" brass	= 1.10
" hard wood	= 1.20

To find Diameter of Pulleys.

Multiply velocity of the driver by its diameter, and divide by the velocity of the driven. Quotient will be diameter of the driven.

Teeth of Wheels,

If not made epicycloidal, are struck out with compasses, the pitch point, A, being the centre from which the point of the next tooth, B C, is struck with radius, A B, the portion B D being radial.



Rule for Change Wheels in Screw-Cutting Lathes.

N = Number of threads, per inch, to be cut.
P = Number of threads, per inch, on traverse screw.
S = Number of teeth in wheel, on mandrel.
W = Number of teeth in stud wheel (gearing in S).
Y = Number of teeth in stud pinion (gearing in T).
T = Number of teeth in wheel, on traverse screw.

$$N = \frac{T\,W}{S\,Y} \qquad W = N\,\frac{S\,Y}{P\,T}$$

Relative Power of Metals to Resist Torsion, Wrought-Iron being Unity.

Wrought-iron	1.00
Cast-iron	.90
Cast-steel	1.93
Gun metal	.27
Brass	.23
Copper	.22
Tin	.13
Lead	.10

Relative Powers of Different Sections to Resist Torsion, the Sectional Areas being Equal, Solid Cylinder being Unity.

Solid Cylinders.	Solid Squares.	Hollow Cylinders whose Inner Diameter is to the Outer as 4 to 10	5 to 10	6 to 10	7 to 10	8 to 10
1.0	.87	1.26	1.44	1.7	2.08	2.74

Strength of Shafting to Resist Torsion.

L = Length of lever in inches, or radius of wheel at which force is applied.

F = Force applied in lbs.
D = Diameter of shaft in inches, if round.
S = Side of shaft in inches, if square.

$D = \sqrt[3]{\frac{F\,L}{1500}}$ for cast-iron.

$D = \sqrt[3]{\frac{F\,L}{1700}}$ for wrou't-iron.

$S = \sqrt[3]{\frac{F\,L}{1800}}$ for cast-iron.

$S = \sqrt[3]{\frac{F\,L}{2000}}$ for wrou't-iron.

$D = \sqrt[3]{\frac{F\,L}{K}}$ } for any other metal.

$S = \sqrt[3]{\frac{F\,L}{x}}$ } for any other metal.

Values of K *and* x.

For cast-steel	K = 3,200	x =	3,800
" gun metal	K = 460	x =	540
" brass	K = 425	x =	500
" copper	K = 380	x =	440
" tin	K = 220	x =	260
" lead	K = 170	x =	200

Supports for Ordinary Shafting.

D = Diameter of shaft, in inches.
S = Distance of supports apart, in feet.

$S = 4.5\sqrt[3]{D^2}$, where power is taken off by riggers between the supports.

$S = 5.\sqrt[3]{D^2}$, where no power is taken off between the supports.

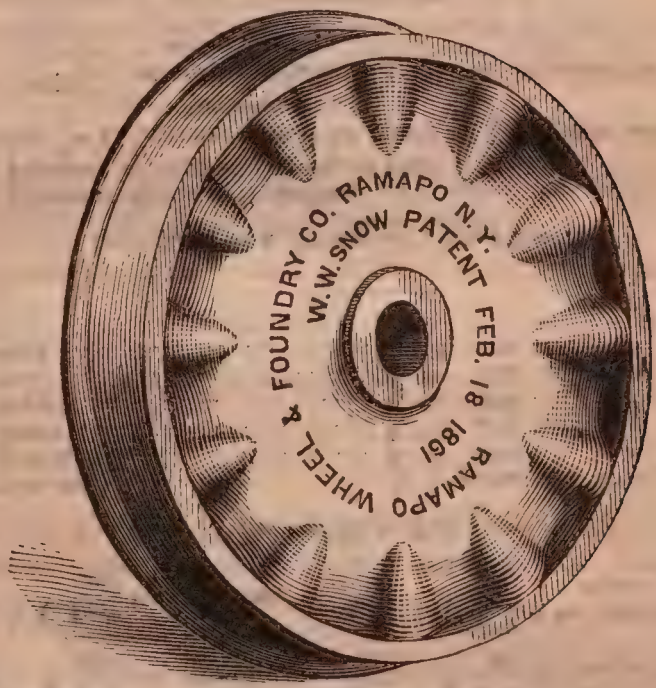
Rain-Fall.

Inches of rain-fall × 2,323,200 = cube feet per square mile.
" " × 14½ = millions of gallons per sq. mile.
" " × 3,630 = cube feet per acre.

Hampo Wheel and Foundry Co.

VIEW OF

W. W. SNOW'S



PATENT CAR WHEEL,

AS MADE BY

THE RAMAPO WHEEL AND FOUNDRY CO.

Centrifugal Fans.

D = diameter of fan; V = velocity of tips of fan, in feet, per second; P = pressure, in pounds, per square inch.

$$V = \sqrt{P \times 97300}; \quad P = \frac{V^2}{97300}$$

Proportion of Fans.—Length of vanes $= \frac{D}{4}$; width of vanes $= \frac{D}{4}$; diameter of inlet $= \frac{D}{2}$; eccentricity of fan $= \frac{D}{10}$; length of spindle journal = 4 diameters of spindle; diameter of smith's forge nozzle, 1⅝ ins.; smithy blast, from 0.25 to 0.3 lbs. per square inch; cupalo blast, 0.8 lb. per square inch.

Power required for Fans.—p = pressure of blast, in pounds, per square inch; A = area of sum of the tuyers in square inches; V = velocity of tips of fan, in feet, per second; H P = indicated horse-power required; $H\,P = .000016\,V^2\,A\,p$.

Wood-Working Machinery.

Velocity of circular saws at periphery, 6,000 to 7,000 feet per minute.

Velocity of the band saw, 2,500 feet per minute.

Velocity of gang saws, 20-inch stroke, 120 strokes per minute.

Velocity of scroll saws, 300 strokes per minute.

Velocity of planing machine cutters at periphery, 4,000 to 6,000 feet per minute.

Travel of work under planing machines, 1-20th of an inch for each cut.

Travel of moulding machine cutters, 3,000 to 4,000 feet per minute.

Travel of squaring-up machine cutters, 7,000 to 8,000 feet per minute.

Speed of wood carving-drills, 5,000 revolutions per minute.

Speed of machine augers, 1½ diameter, 900 revolutions per minute.

Speed of machine augers, ¾ diameter, 1,200 revolutions per minute.

Gang saws require for 45 superficial feet of pine per hour, 1 horse-power indicated.

Circular saws require for 75 superficial feet of pine per hour, 1 horse-power indicated.

In oak or hard wood, ¾ths of the above quantity, require 1 horse-power indicated.

Sharpening Angles of Machine Cutters.

Adzing soft wood across the grain, 30°.
Ordinary soft-wood planing machines, 35°.
Gouges and plowing machines, 40°.
Hard-wood tool cutters, 50° to 55°.

Depreciation of Machinery, etc.,

Per annum on first cost.

	Depreciation.	Wear and Tear.	Total.
Engines	6 per cent.	3 per cent.	9 per cent.
Boilers	10 "	3 "	13 "
Machines	7½ "	3½ "	11 "
Millwork and Gearing.	4 "	2½ "	6½ "
Bands and Belts	— "	45 "	45 "

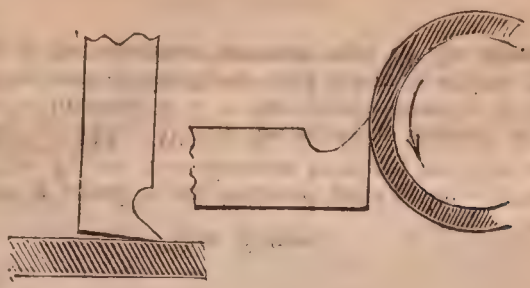
Iron-Turning Tools.

Surface-bored should be at rate of..... 78.54 feet per minute.
Surface-turned " " .....157.08 " "

Form of Iron-Cutting Tools.

To form and place any tool to cut any surface, let the end be so formed and placed as to make the least possible angle with the surface to be cut, and whatever degree of acuteness may be considered requisite; let the keenness be given by hollowing out the surface on which the shavings slide.

FORM OF IRON-CUTTING TOOLS.



TOOL GAUGE,

For Drills, Lathes, Planes, etc.

A convenient tool gauge, to ascertain if a tool is ground to proper angle, consists of a plate of iron 15 inches long by 5 inches, ¼ inch thick, in which is inserted a cone toward the end of the plate, the cone turned with a taper making the angle formed by the sides of the cone and surface of the plate about 3 degrees.

MECHANICAL POWERS.

LEVERS.

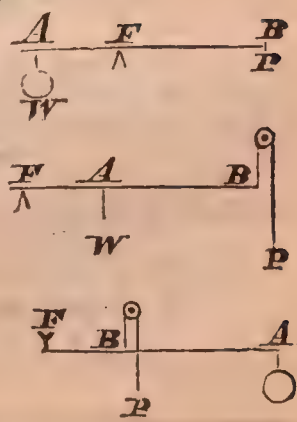
W = Weight to be raised.
P = The Power.
F = The Fulcrum.

$$P = \frac{W \times A\,F}{F\,B.}$$

$$W = \frac{P \times F\,B}{A\,F.}$$

$$F\,B = \frac{W \times A\,F}{P.}$$

$$A\,F = \frac{P \times F\,B}{W.}$$



Ramapo Wheel and Foundry Co.

Pulley.

N = Number of sheaves in the lower block.
P = Power required.
W = The weight to be raised.

$$P = \frac{W}{2\,N.}$$

Inclined Plane.

P = The power.
W = The weight.
L = The length of the plane.
H = The height.
B = The base or horizontal length.

When the line of traction is parallel to L,

$$P = \frac{W\,H}{L.}$$

$$W = \frac{P\,L}{H.}$$

When the line of traction is parallel to B,

$$P = \frac{W\,H}{B.}$$

$$W = \frac{P\,L}{H.}$$

The Screw.

The screw is equal to an inclined plane, the circumference being equal to B, and the distance between two threads equal H. $L = \sqrt{B^2 + H^2}$. When the screw is worked by a lever, as is generally the case, if C = the circumference of the circle formed by the end of the lever and through which the power P acts, and *d* the distance between two of the threads, then

$$W = \frac{P\,C}{d.}$$

The Wedge.

When two bodies are forced asunder by means of a wedge in a direction parallel to its back:

Rule.—As the length of the wedge is to half of its back or head, so is W to P.

When only one of the bodies is movable:

Rule.—As the length of the wedge is to its back, so is W to P.

Crabs and Cranes.

Let A B C, etc. = Diameters of the wheels.
" a b c, etc. = " " pinions.
D = " " drum or barrel.
H = " " circle formed. by the winch or handle.

P = Power applied to winch.
W = Weight to be raised.

$$P = W \frac{D\,(a\ b\ c,\ \text{etc.})}{H\,(A\ B\ C,\ \text{etc.})}$$

$$W = P \frac{H\,(A\ B\ C,\ \text{etc.})}{D\,(a\ b\ c,\ \text{etc.})}$$

Allow 15 lbs. for each man turning the handle of a crab or crane, at a velocity of 200 feet per minute when the work is continuous, and 20 lbs when there are intervals of rest, which is usually the case.

Radius of handle	15 to 18	inches.
Height of axle above ground	33 to 36	"
Pitch of first motion wheels	$1\frac{1}{4}$ to $1\frac{1}{2}$	"
Width of "	3 to 4	"
Pitch of second movers	1 to $1\frac{1}{4}$	"
Width	2 to 3	"
Pinion on axle of winch	8 to 12	teeth.

Power Gained by Blocks.

Let n = number of pulleys in the movable block; the power gained by the two blocks will be $= 2\,n$.

To compute the power required to raise a given weight, the number of parts of the cord supporting the lower block being given: $\frac{W}{n} = P$; or, $n \times P = W$, n representing the number of parts of the cord sustaining the lower block.

To compute the weight a given power will raise, the number of parts of the cord supporting the lower block being given: $P \times n = W$.

To compute the number of cords necessary to sustain the lower block, the weight and power being given $= \frac{W}{P} = n$.

CRANES.

When the Post is Supported at both the Top and Foot.

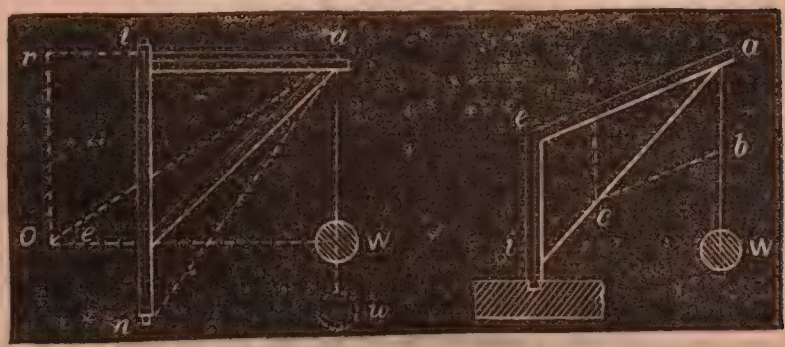


Fig. 1. Fig. 2.

The usual form of a crane is that of a right-angled triangle, the three sides being the post or upright, the jib or arm, and the stay or strut, which is the hypothenuse of the triangle. When the jib and stay are of equal length, the stay being the diagonal of a square, this form is theoretically the strongest, the whole stress or weight being borne by the stay, compressing it in the direction of its length, the stress upon it, as compared to the weight supported, being as the diagonal to the side of the square, or as 1.4142 to 1; consequently, if the weight borne by the crane

is 2,000 lbs., the thrust or compression upon the stay will be 2828.4 lbs., or as *a e* to *e* W, fig. 1. The weight, W, is sustained by the rope or chain, and the tension is equal upon both parts of it; that is, on the two sides of the square, *i a* and *e* W, consequently the jib, *i a*, has no stress upon it, and serves merely to retain the stay, *a e*.

If the foot of the stay be set at *n*, the thrust upon it, as compared with the weight, will be as *a n* to *a w*; and if the chain or rope from *i* to *a* is removed, and the weight is suspended from *a*, the tension on the jib will be as *i a* to *a* W. If the foot of the stay is raised to *o*, the thrust, as compared with the weight, will be as the line *a o* is to *a* W, and the tension on the jib will be as the line *a r*.

When the Post is Supported at the Foot only.

If the post is wholly unsupported at the top, and the foot is secured up to the line *o w*, then the weight, W, acting with the leverage *e* W, will tend to rupture the post at *e*, with the same intensity or effect as if twice that weight was laid upon the middle of a beam, which is assumed to be supported at both ends, the dimensions of the beam being alike to those of the post, and the depth being that of the line of rupture of the post, or the force exerted to rupture the post, will be represented by the weight or stress, W, multipled by 4 times the length of the lever, *e* W, divided by the depth or thickness of the post in the line of the stress, squared, and multiplied by the breadth of it, and the value of the material of which it is composed.

To Compute the Stress upon the Stay of a Crane.

Rule—Multiply the length of the stay, in feet, by the weight to be borne, in pounds; divide the product by the height of the jib from the point of bearing of the stay, in feet, and the quotient will give the stress or thrust, in pounds.

Ex.—The length of the stay of a crane is 30 feet, the height of the post is 28 feet, and the weight to be borne is 20,000 lbs.—what is the stress?

$$\frac{30 \times 20{,}000}{28} = 21{,}428 + \text{lbs.}$$

To Compute the Dimensions of the Post of a Crane,

When the Post is Supported at the Feet only.

Rule—Multiply the weight or stress to be borne, in pounds, by the length of the jib, in feet, measured upon a horizontal plane; divide the product by the *value* of the material to be used, and the product, divided by the breadth, in inches, will give square of the depth, also in inches.

Ex.—Stress upon a crane is 22.400 lbs., the distance of it from centre of the post is 20 feet—what should be dimensions of a white oak post?

Value of American white oak post = 50; assumed breadth = 12 ins.; $\frac{22{,}400 \times 20}{50} = 8{,}960$, and $\frac{8{,}960}{12} = 746.67$; then $\sqrt[2]{746.67} = 27.32$ ins.

Ramapo Wheel and Foundry Co.

When the Post is Supplied at Both Ends.

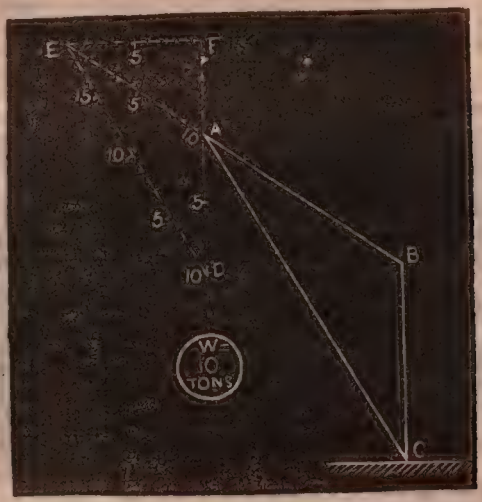
RULE—Multiply the weight or stress to be borne, in pounds, by twice the length of the jib, in feet, measured upon a horizontal plane; divide the product by the *value* of the material to be used, and the product, divided by 4 times the breadth, in inches, will give the square of the depth, also in inches.

Ex.—Take same elements as in preceding case.

$$\text{Assumed breadth} = 10 \text{ ins.; then } \frac{22{,}400 \times 20 \times 2}{50} = 17{,}920,$$

$$\text{and } \frac{17{,}920}{4 \times 10} = 448, \text{ and } \sqrt[2]{448} = 21{,}166 \text{ ins.}$$

COMPUTATION OF THE STRAINS ON A CRANE BY CONSTRUCTION.



Let A B C represent a crane, A B the suspension rods, A C the jib, B C the crane-post; weight, W, assumed to be 10 tons in diagram. With a scale draw A D = W = 10 tons; from D draw D E parallel to the jib until it intersects line, A B, produced to E; from E draw the horizontal line, E F, and produce the line A D, to meet it at F. Strains may be measured as follows: Thrust on jib = E D = 19¼ tons in the diagram; strain on the suspension rod = A E = 11¼ tons; the crane-post may be considered as a beam fixed at one end, C, and a weight = E F, applied at the other end, B. The weight, E F = 9¼ tons in the diagram.

To Find the Centre of Gravity.

Suspend a body successively in three or more positions; then the intersection of the vertical lines from each point of suspension will be the centre of gravity.

Position of Centre of Gravity at various figures.

Parallelogram	at intersection of diagonals.
Pyramid or cone	= ¼ height from base.
Paraboloid	= ⅓ " "
Hemisphere	= ⅜ " "
Cylinder and sphere	= at centre.
Segment of circle from centre	$= \frac{\text{Chord}^3}{12 \text{ area}}$
Sector of circle from centre	$= \frac{2 \text{ Chord} \times \text{Rad.}}{3 \text{ arc}}$

Centre of Percussion.

Distance from Centre of Motion.

In a straight bar, suspended at extremity	⅔ length.
Wheels	¾ rad.
Long cone, suspended at apex	4-5 height.

Centre of oscillation is same as that of percussion.

Centre of Gyration.

Position of centre of gyration from centre of motion, in a straight bar, revolving about one end	= .557 length.
Ditto, revolving about centre	= .289 "
Circular plate, revolving about centre	= .707 rad.
Ditto, revolving about its diameter	= .5 "
Circular Ring, revolving about its diam.	= .707 "
Sphere, " " "	= .632 "
Hollow Sphere, " " "	= .816 "
Cylinder, revolving about its axis	= .707 "
Cone, " " "	= .557 R. of base
Cone (right-angled), revolving ab't its apex.	= .866 height.

Gravity.

N = Number of seconds.
S = Space fallen through, in feet.
V = Velocity, in feet, per second, acquired in N seconds or S space.

$V = N \times 32.166.$ $V = \sqrt{S \times 64.33}$

$S = N^2 \times 16.083.$

Table of Velocity of Falling Bodies.

Time, in seconds	1	2	3	4	5	6	7	8	9	10
Space, in feet	16	64	145	257	402	579	788	1030	1303	1609
Velocity, in feet, per sec'd.	32	64	96	128	161	193	225	257	289	321

Falling Bodies (in Vacuo).

Velocities Due to Different Heights.

Fall, in Feet.	Velocity—Ft. per Sec.	Fall, in Feet.	Velocity—Ft. per Sec	Fall, in Feet.	Velocity—Ft. per Sec.
1	8.	50	57	275	133
2	11.3	60	62	300	139
3	13.9	70	67	325	144
4	16.	80	72	350	150
5	18.	90	76	375	155
10	25.	100	80	400	160
15	31.	125	90	450	170
20	36.	150	98	500	179
25	40.	175	106	550	188
30	44.	200	113	600	196
35	47.	225	120		
40	51.	250	127		

Pile Driving.

D = Set of pile by the last blow, in inches.
H = Height the ram has fallen, in inches.
L = Safe load for the pile, in cwts.

$L = \frac{W\,H}{8\,D}$ approximately.

W = Weight of ram; that is, 450 lbs. in ordinary pile engines.

Centrifugal Force.

W = Weight of revolving body, in pounds.
R = Radius, or distance from centre of motion, in feet.
F = Centrifugal force, in pounds.
N = Number of revolutions per minute.

$$F = .00033\ W.\ R.\ N^2.$$

$$W = \frac{3{,}030\ F.}{R.\ N^2.}$$

Fly-Wheels.

Weight of rim should be 85 to 95 lbs. per actual horse-power, momentum of wheel being 4½ times that of the piston.

Diameter, 3 to 4 times that of the stroke of engine.

Single-acting engines, fly-wheel to be 5 times heavier than in double-acting engines.

To compute Weight of Rim.—Multiply the mean effective pressure upon the piston, in pounds, by its stroke, in feet, and divide the product by the product of the square of the number of revolutions, the diameter of the wheel, and .00023.

For a light wheel, multiply by .0003; for a heavy one, by .00016.

To compute Dimensions of the Rim.—Multiply the weight, in pounds, by .1, and divide the product by the mean diameter of the rim, in feet; the quotient will give the sectional area of the rim in square inches of cast-iron.

Vibrations of the Pendulum.

L = Length of pendulum, in feet.
T = Time of one oscillation, in seconds.
l = Length of pendulum, in inches.

$$T = .16\sqrt{l}$$

$$T = .554\sqrt{L}$$

A pendulum making one oscillation per second, in the latitude of New York, is 39.1013; London, 39.1386 inches long.

Animal Power.

Working 8 hours per day.	In pounds raised 1 ft. per minute.
Horse	21,000
Ox	12,000
Mule	10,000
Ass	3,500
Man, as in rowing	4,000
Ditto, on tread-wheel	3,100
Turning a handle	2,600

Tractive Force for Horses.

Rate in miles per hour =	2	3	3½	4	4½	5
Tractive force exerted by horse, in lbs. =	166	125	104	83	62	41

Traction on Roads.

Resistence in lbs. per ton on different roads, exclusive of gravity.

Stone tramway	20 lbs.	per ton.
Paved roads	33 "	"
Macadamized roads	44 to 67 "	"
Gravel	150 "	"
Soft, sandy, and gravelly ground	210 "	"

Maximum Power of a Horse on Canals at Different Speeds.

V = Velocity, in miles, per hour.
H = Duration of work, in hours, per day.
L = Total load drawn by one horse on canal, per ton.

V	H	L	V	H	L
2 1-2	11 1-2	520	6	2	30
2	8	243	7	1 1-2	19
3 1-2	5 9-10	153	8	1 1-8	13
4	4 1-2	102	9	9-10	9
5	2 9-10	52	10	3-4	6 1-2

Force of the Wind.

Miles per Hour.	Feet per Minute.	Feet per Second.	Force in pounds per square foot.	Description.
1	88	1.47	.005	Hardly perceptible.
2	176	2.93	.020	Just perceptible.
3	264	4.4	.044	
4	352	5.87	.079	Gentle breeze.
5	440	7.33	0.123	
10	880	14.67	0.492	Pleasant breeze.
15	1,320	22.	1.107	
20	1,760	29.3	1.970	Brisk gale.
25	2,200	36.6	3.067	
30	2,640	44.	4.429	High wind.
35	3,080	51.3	6.027	
40	3,520	58.6	7.870	Very high wind.
45	3,960	66.0	9.900	
50	4,400	73.3	12.304	Storm.
60	5,280	88.0	17.733	Great storm.
70	6,160	102.7	24.153	
80	7,040	117.3	31.490	Hurricane.
100	8,800	146.6	49.200	

Blowing Engines.

Capacity of air vessel = 20 times the capacity of the blowing cylinder if the cylinder is single-acting.
" " = 10 times if double-acting.

Velocity of air in the passages should not exceed 35 feet per second. Density of blast for iron furnaces, from 2½ to 3 lbs. per square inch.

Each smith's forge requires 150 cube feet of air per minute. Density of smith's forge blast ¼ lb. per square inch. Each ton per hour melted in cupola requires 3,500 cube feet per minute. Each

finery forge requires 100,000 cube feet air for each ton refined; each blast furnace 20 cube feet per minute for each cube yard capacity of furnace.

HYDRAULICS.

To Find the Time a Cistern Will Take in Filling,

When a Known Quantity of Water is going in, and a Known Quantity of that Water is going out, in a given time.

Rule.—Divide the contents of the cistern, in gallons, by the difference of the quantity going in and the quantity going out, and the quotient is the time in hours and parts that the cistern will take in filling.

To Find the Time a Vessel Will Take in Emptying Itself of Water.

Rule.—Multiply the square root of the depth in feet by the area of the falling surface in inches; divide the product by the area of the orifice, multiplied by 3.7, and the quotient is the time required in seconds, nearly.

Any Two Dimensions of a Square or Rectangular Cistern being Given,

To find the Third, that shall contain any number of U. S. Gallons Required.

Rule—Divide the number of gallons that the cistern is required to contain by the product of the two dimensions multiplied by 7.48 if the dimensions are in feet, or by .004329 if the dimensions are in inches, and the quotient will be the third dimension of the cistern.

Flow of Water through Orifices.

Rule—To find quantity discharged per minute, multiply area of the orifice in square feet by the square root of the height of the level of the water above the orifice in feet, and the product multiplied by 297.6, equal discharge in cubic feet, nearly.

Flow over Weirs.

Head equal height of the level of the water above the edge of the weir, the level being taken where it has not begun to fall toward the weir—to find discharge in cubic feet per minute, multiply length of the weir in feet by square root of the cube of the head in feet, and by 192.6.

Flow of Water through Canals, Troughs, etc.

To find Mean Velocity of the Flow.

Multiply the head or fall in feet by the area of the cross section of the stream in square feet, and divide the product by the length of the channel in feet; the square root of the quotient multiplied by 774.6, equal velocity in feet per minute.

To find discharge per minute in cubic feet, multiply the velocity found by last rule by the sectional area of the stream in square feet.

To find Pressure of Water in Pounds, per Square Inch,

Exerted by a Column of Water.

Multiply the height of the column in feet by 0.434.

To find the Head in Feet, Pressure being Known.

Multiply the pressure per square inch by 2.31.

Pressure per square foot, equal height of column in feet, multiplied by 62.4.

Pressure of Water.

The weight of water or of other liquids is as the quantity, but the pressure exerted is as the vertical height.

Fluids press equally in all directions; hence any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

Lateral Pressure.

The lateral pressure of a fluid on the sides of a vessel in which it is contained, is equal to the product of the length multiplied by half the square of the depth, and by the weight of the fluid in cubic unity of dimensions.

Centre of Pressure.

The centre of pressure and the centre of percussion in a fluid is two-thirds the depth from the surface.

Discharge of Water.

In circular apertures in a thin plate on the bottom or side of a reservoir, the issuing stream tends to converge to a point distant at about one-half its diameter from outside the orifice, reducing the quantity nearly $\frac{5}{8}$ths from quantity due to the velocity corresponding to the height. When water issues from a short tube, the flow is less contracted than in the former case, as 16 to 13.

With a conical aperture whose greater base is the aperture, the height of the frustrum being half the diameter of the aperture, and the area of the small end to the area of the large end as 10 to 16, there will be no contraction of the vein. Hence this form gives the greatest flow.

The quantity of water flowing from a verticle rectangular aperture reaching to the surface is two-thirds of the quantity that would flow out of the same aperture placed horizontally at the depth of the base.

The quantity of water discharged during the same time by the same orifices under different heads, are nearly as the square roots of the corresponding heights of the water in the reservoir above the surface of the orifices.

Small orifices, on account of friction, discharge proportionately less fluid than those which are larger and of the same figure, under the same pressure.

Circular apertures are the most efficacious, having less rubbing surface under the same area.

If the cylindrical horizontal tube through which water is discharged be of greater length than the diameter, the discharge is much increased; can be increased to advantage to four times the diameter of the orifice.

Conducting Pipes.

The less the diameter of the pipe, the less, proportionally, is the discharge of the fluid.

The greater the length of the conduit pipe, the less the discharge.

To find diameter of pipes to discharge given quantity of water per minute in cubic feet: *Rule*—Multiply the square of the quantity in cubic feet per minute by .96, and the product equals the diameter of the pipe in inches.

Standard Water Pipes.

Bore in inches.	Thickness of Metal.	Depth of Socket.	Thickness of Socket.	Space for Packing.	Weight* of 9 feet length.
	Inches.	Inches.	Inches.	Inches.	Lbs.
3	5-16	3½	⅜	⅜	108
4	5-16	3½	7-16	⅜	154
5	⅜	3¾	7-16	7-16	184
6	⅜	3¾	½	7-16	224
7	⅜	3¾	½	7-16	256
8	7-16	3¾	½	7-16	340
9	7-16	4	9-16	½	383
10	½	4	⅝	½	492
11	½	4	⅝	½	526
12	9-16	4	11-16	½	640
14	⅝	4	11-16	½	844

* The 9-feet length is taken from the end of one pipe to the end of the next, when laid.

Table of Diameter of Pipes,

Of Sufficient Dimensions to Discharge a Required Quantity of Water per Minute.

Cubic feet.	Diameter in inches.	Cubic feet.	Diameter in inches.	Cubic feet.	Diameter in inches.
1	.96	18	4.07	130	10.94
2	1.36	20	4.29	140	11.35
3	1.66	25	4.80	150	11.75
4	1.92	30	5.25	160	12.14
5	2.15	35	5.67	170	12.51
6	2.35	40	6.07	180	12.67
7	2.60	45	6.53	190	13.23
8	2.72	50	6.80	200	13.57
9	2.88	55	7.12	225	14.40
10	3.04	60	7.43	250	15.17
11	3.18	70	8.03	275	15.91
12	3.33	80	8.60	300	16.62
13	3.46	90	9.10	350	17.95
14	3.60	100	9.60	400	19.20
15	3.72	110	10.06	500	20.46
16	3.84	120	10.51	600	23.51

Cubic feet $\times$ 7.48 = U. S. gallons.

To find the Number of United States Gallons contained in Foot of Pipe of any given Diameter.

Rule.—Square the diameter of the pipe in inches, multiply the square by .0408; the product is U. S. gallons.

Power Required to Raise Water to any Height.

Multiply perpendicular height of the water, in feet, by the velocity, also in feet, and by the square of the pump's diameter in inches, and again by .341; divide the product by 33,000, and one-fifth of the quotient added to the whole quotient, will be the number of horse-power required.

Table of the Power Required to Raise Water from Deep Wells.

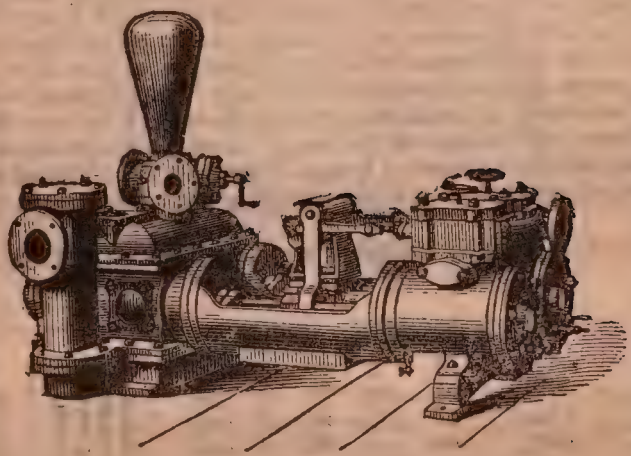
Diameter of pump barrel.	Description of pump.	Quantity of water raised per hour.	Maximum depth from which this quantity can be raised by each unit of power.			
			One man turning a crank.	One donkey working a gin.	One horse working a gin.	One-horse power steam engine.
In.		Gallons.	Feet.	Feet.	Feet.	Feet.
2	Double action lift and force pump.	225	80	160	560	880
2½		360	50	100	350	550
3		520	35	70	245	385
3½		700	25	50	175	275
4		900	20	40	140	220

H. R. Worthington's Duplex Steam Pump.

The valve motion is the prominent and important peculiarity of this pump, as being that to which it owes its exemption from noise or concussive action. Two steam pumps are placed side by side, and so combined as to act reciprocally upon the steam valves of each other. The one piston acts to give steam to the other, after which it finishes its own stroke, and waits for its valve to be acted upon before it can renew its motion. This pause allows all the water valves to seat quietly, and removes everything like harshness of motion. As one or the other of the steam valves must be always open, there can be no centre or dead point. The pump is therefore always ready to start when steam is admitted, and is managed by the simple opening and shutting of a valve.

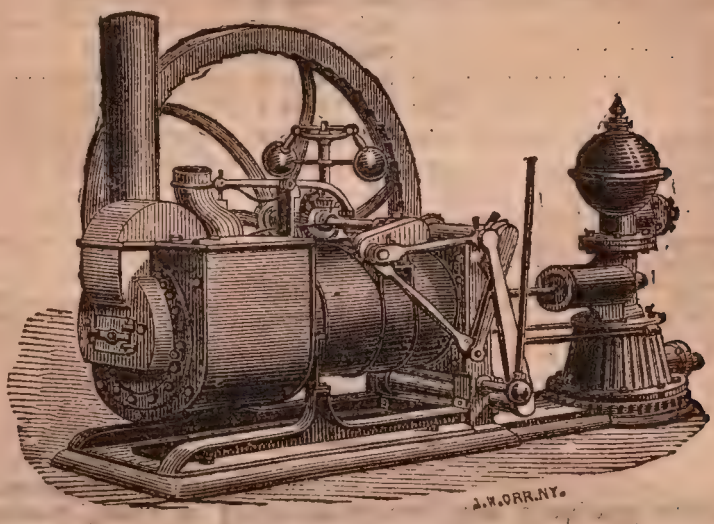
H. R. WORTHINGTON'S

Duplex Steam Pump.



Diameter of Steam Cylinder in inches.	Diameter of Water Plungers in inches.	Length of Stroke in inches.	Single Strokes per minute, varying with kind of work and pressure.	Displacement in gallons per single stroke.
4½	2¾	4	100 to 150	22-100
6	4	6	80 " 125	68-100
7½	4½	10	80 " 125	1 44-100
10	6	10	75 " 125	2 55-100
14	7	10	75 " 125	3 48-100
14	10¼	10	75 " 125	7 46-100
16	10¼	10	75 " 125	7 46-100
14	14	10	75 " 125	14

ERICSSON CALORIC PUMPING ENGINE.



Size Cylinder.	Size Pump.	Height of Column of Water.	Per Hour in U. S. Gallons.
12-inch.	3-inch.	125 feet.	560
12 "	4½ "	50 "	1,290
15 "	3 "	145 "	665
15 "	5 "	60 "	1,800
18 "	2 "	290 "	720
18 "	6 "	70 "	2,890
24 "	5 "	185 "	2,395
24 "	8 "	70 "	6,135

The hot-air engine was invented by Mr. Stirling, modified and improved by Mr. John Ericsson.

It consists of a pump which compresses air into a receiver, in

which it receives an additional charge of heat, and a cylinder, the piston of which is worked by the heated air as it escapes. The difference between the work produced by the cylinder and that absorbed by the pump, constitutes the force of the engine; its power is due to the considerable expansibility of air by heat.

The economy of any perfect thermo-dynamic engine depends upon the range of temperature obtained in it. The lowest temperature being that of the earth is generally nearly constant; the higher the highest temperature of the air can be raised, the more economical will be the engine. The limit of heat will depend upon the temperature at which air acts chemically upon the metals employed, as well as upon the power of the metals themselves to resist the destructive action of heat.

The air engine not being liable to explosion or derangement of parts, requiring no water supply, and but little fuel and attendance, make it probably the cheapest method of obtaining power, and for the use of railway companies for raising water at stations has given the greatest satisfaction.

Messrs. James A. Robinson & Co., New York, will supply full particulars on application.

Expansion of Air.

(*Dalton.*)

Temperature.	Expansion.	Temperature.	Expansion.
32°	1.	80°	1.110
33	1.002	85	1.121
34	1.004	90	1.132
35	1.007	95	1.142
40	1.021	100	1.152
45	1.032	200	1.354
50	1.043	212	1.376
55	1.055	302	1.558
60	1.066	392	1.739
65	1.077	482	1.912
70	1.089	572	2.028
75	1.099	680	2.312

Hydraulic Ram.

Q = Quantity of water used, in cube feet, per minute.
h = Head of water, in feet.
H P = Effective horse-power.

$$Q = \frac{882\ H\ P}{h} \qquad H\ P = .00113\ Q\ h$$

The hydraulic ram owes its efficacy to the fact that when a flow of water in a pipe is suddenly stopped, a considerable force is generated by the momentum of the water, by its change from a state of motion to a state of rest. In practice, the pipe conveying water from the reservoir or head, connects with a chamber which has a valve opening downward, or outlet valve, allowing the current of water to pass on or escape when the valve is open; but on flowing, the current in the pipe acquires sufficient force to close this valve, which checks the flow in the pipe. The current is thus suddenly stopped; this causes a reaction, which produces pressure sufficient to open another valve (inlet valve) between the current-pipe and an air-chamber, and a portion of water enters by means of the force of the current, but by so doing the current has spent its force; the outlet valve at the end of the chamber falls by its own weight, and the pressure in the pipe ceasing, the inlet valve in the air-chamber falls and closes the opening. The condition of things then is as at first; the water again acquires a momentum which closes the outlet valve and forces more water again into the chamber. A very slight pressing column is capable of raising a very high ascending one. In all cases the drive-pipe or inlet pipe must be sufficiently long to prevent water being forced back into the reservoir. The air-chamber serves to keep up a steady supply from the reservoir, preventing spasmodic action. To prevent admixture of air with the water in the air-chamber, which is caused by pressure of the water when raised to a great height, a small hole should be made on the upper side of the inlet pipe, immediately in front of the same. By the action of the ram at each stroke, a partial vacuum is formed below the air-chamber, and the air rushing through the small hole in the inlet pipe, passes into the air chamber, making good that which the water absorbs.

Ramapo Wheel and Foundry Co.

Rule to Calculate Amount of Water Raised.

In conveying water from 80 to 100 feet, one-seventh part of the water drawn from the spring can be raised and discharged, at any elevation above the ram, five times as high as the fall which is applied to the ram, or one-fourteenth part can be raised and discharged say ten times as high as the fall applied, and so on in proportion as the fall or rise is varied.

By a ram under a head of 5 feet, of every 7 gallons drawn from the spring, one gallon may be raised 25 feet, or half a gallon 50 feet, or with 10 feet fall, of every 14 gallons from the spring, one may be raised to the height of 100 feet above the ram; and so on, in proportion as rise and fall is increased or diminished; it is applicable to fall of 18 inches, and water can be conveyed by a ram 3,000 feet, and elevated 200 feet.

Rules for Dimenisions for Pipes for Rams.

Size of Ram.	Drive Pipe.	Discharge Pipe.
No. 2.....	¾ inch for 40 to 50 feet.	⅜ inch.
No. 3.....	1 " " "	½ "
No. 4.....	1¼ " " "	½ "
No. 5.....	2 " " "	¾ "
No. 6.....	2½ " " "	1 "
No. 7.....	4 inch for 50 to 80 feet.	2 "

Table of Results of Operation of Hydraulic Rams.

(*Haswell.*)

No. of Strokes.	Height of Fall.	Elevation.	Water Expended.	Water Raised.	Useful Effect.
Min.	Feet.	Feet.	Cubic Feet.	Cubic Feet.	
66	10.66	26.3	1.71	.543	.9
50	9.93	38.6	1.93	.421	.85
36	6.05	38.6	1.43	.169	.75
31	5.06	38.6	1.98	.058	.35
15	3.22	38.6	1.58	.014	.18
10	22.8	196.8	.38	.029	.67

TIMBER, WOODS, ETC.

The best timber grows in a dark soil, intermixed with gravel. For cutting, trees should be selected in latter part of July. Sound trees have green and fresh leaves, top branches well leaved, bark even, and uniform color; the contrary, and leaves turning yellow in July, separating of the bark from the wood, rough bark, and parasitic plants upon the bark, denote unsound trees. The proper time for cutting is midsummer or midwinter. As soon as a tree is felled the bark should be taken off; to be raised from the ground and timber hewed to size. Quality of timber is indicated by color, which should be nearly uniform to the heart, deeper towards the centre; white spots indicate decay and sap wood. Dry rot is indicated by yellow stains.

Seasoning Timber.

Timber requires from 2 to 8 years for thorough seasoning. Green timber contains 37 to 48 per cent. of liquid. By exposure to the air one year it loses from 18 to 25 per. cent., and when seasoned it yet contains 10 to 15 per cent. of liquid; oak loses 1-5 of its weight in seasoning, 1-3 when perfectly dry. Timber is improved and rendered less liable to warp by being immersed in water some weeks. If long immersed, when exposed to the air it becomes brashy and useless. Timber seasoned should be piled under shelter and kept dry; should have a free and gentle circulation af air; bottom layer to be placed on timbers 24 ins. from the ground, each subsequent layer to have an inch space between them.

Decrease in Dimensions of Timber by Seasoning.

Woods.	Inches.
Canada Cedar	14 to 13¼
Elm	11 to 10¾
English Oak	12 to 11⅝
Northern Pitch Pine	10×10 to 9¾×9¾
Southern Pitch Pine	18⅜ to 18¼
Spruce	8½ to 8⅜
American White Pine	12 to 11⅞
Northern Yellow Pine	18 to 17⅞

BUILDING.

Weight of Timber Work, Timber Flooring.

Multiply breadth in feet by length in feet by the thickness in inches, and by one of the following factors, according to the material: For elm use, 3.50 lbs.; for yellow pine, 3.42; for white pine, 2.97; for dry oak, 4.85.

To find the Weight of Timber Beams, Posts, and Joists.

Multiply length in feet by the breadth in inches and the depth in inches, and the product by one of the following factors: For elm, 2.92; yellow pine, 2.85; white pine, 2.47; dry oak, 4.04.

TIMBER.

Weight per Thousand (M), Feet Board Measure.

	Dry.	Partial Seasoned.	Green.
Pine and hemlock	2,500 lbs.	2,750 lbs.	3,000 lbs.
Norway and yellow pine	3,000 "	4,000 "	5,000 "
Oak and walnut	4,000 "	5,000 "	
Ash and Maple	3,500 "	4,000 "	

Weight per Cubic Foot.

Ash	50 lbs.	Mahogany	50 lbs.
Beech	43 "	Oak	58 "
Birch	44 "	Yellow pine	41 "
Elm	37 "	White pine	29 "
Larch	35 "	Yew	50 "

Shingles.

1 bundle of 16-inch shingles will cover 30 square feet;
1 " 18-inch " " 33 " "
when laid 5½ inches to the weather.

6 pounds 4-penny nails will lay 1,000 split pine shingles.

Clapboards.

1 bundle laid 3½ inches to the weather, will cover 26 square feet. To be laid with 5-penny nails.

Flat or Broad Measure,

For the Mensuration of Timber.

Beadth in ins.	Area of a Lineal Feet.	Breadth in ins.	Area of a Lineal Foot.	Breadth in ins.	Area of a Lineal Foot.
¼	.0208	4¼	.3542	8¼	.6875
½	.0417	4½	.375	8½	.7084
¾	.0625	4¾	.3958	8¾	.7292
1	.0834	5	.4167	9	.75
1¼	.1042	5¼	.4375	9¼	.7708
1½	.125	5½	.4583	9½	.7917
1¾	.1459	5¾	.4792	9¾	.8125
2	.1667	6	.5	10	.8334
2¼	.1875	6¼	.5208	10¼	.8542
2½	.2084	6½	.5416	10½	.875
2¾	.2292	6¾	.5625	10¾	.8959
3	.25	7	.5833	11	.9167
3¼	.2708	7¼	.6042	11¼	.9375
3½	.2916	7½	.625	11½	.9583
3¾	.3125	7¾	.6458	11¾	.9792
4	.3334	8	.6667		

Area of a lineal foot, multiplied by length in feet, will give superficial content in square feet.

A board is 1 foot 3¾ inches wide × 21 feet long. What is its superficial content? 1 foot = 1.

3¾ ins. = .3125. 1.3125 × 21 = 27.5 square feet.

TABLE OF ¼ GIRTHS.

¼ Girth in inches.	Area in feet.	¼ Girth in inches.	Area in feet.	¼ Girth in inches.	Area in feet.
6	.250	12¼	1.04	19	2.50
¼	.272	½	1.08	½	2.64
½	.294	¾	1.12	20	2.77
¾	.317	13	1.17	20½	2 91
7	.340	¼	1.21	21	3.06
¼	.364	½	1.26	21½	3.20
½	.390	¾	1.31	22	3.36
¾	.417	14	1.36	½	3.51
8	.444	¼	1.41	23	3.67
¼	.472	½	1.46	½	3.83
½	.501	¾	1.51	24	4.00
¾	.531	15	1.56	½	4.16
9	.562	¼	1.61	25	4.34
¼	.594	½	1.66	½	4.51
½	.626	¾	1.72	26	4.69
¾	.659	16	1.77	½	4 87
10	.694	¼	1.83	27	5 06
¼	.730	½	1.89	½	5.25
½	.766	¾	1.94	28	5.44
¾	.803	17	2.00	½	5.64
11	.840	¼	2.06	29	5 84
¼	.8781	½	2.12	½	6.04
½	.918	¾	2.18	30	6.25
¾	.959	18	2 25		
12	1.000	½	2.37		

Area corresponding to the ¼ girth in inches × length in feet = solidity in feet and decimal parts.

To Find Solidity of Round Timber.

When all dimensions are in feet.

Length × by square of ¼ mean girth = cubic feet.

When length in feet, girth in inches.

Multiply as above, and ÷ by 144.

When all dimensions are in inches.

Multiply as above, and ÷ by 1728.

To Find Solidity of Square Timber.

When all dimensions are in feet.

Length × breadth × depth = cubic feet.

When either dimensions are in inches.

Multiply as above, and ÷ by 12.

When any two of the dimensions are in inches.

Multiply as above, and ÷ by 144.

For Board Measure, depth always equals 1 inch.

To Find Surface in Square Feet, proceed as per rules for solidity of square timber.

Stair-Cases.

Width of Tread.	Height of Riser.	Width of Tread.	Height of Riser.
6 inches.....	8½ inches.	10 inches.....	6½ inches.
7 "	8 "	11 "	6 "
8 "	7½ "	12 "	5½ "
9 "	7 "	13 "	5 "

Dimensions for Timber Roofing.

(*Tredgold.*)

A = Area of section in inches.
B = Breadth in inches.
D = Depth in inches.
L = Length of piece in feet.
S = Span of roof in feet.

KING POST. $A = L\,S \times 0.12$ for pine, or by 0.13 for oak.

$$B = \frac{A}{D.} \qquad D = \frac{A}{B.}$$

QUEEN POST. $A = L\,p \times 0.27$ for pine, or 0.32 oak.
p being the length in feet of that part of the beam supported by the queen post.

TIE BEAM. $D = \frac{l}{\sqrt[3]{B}} \times 1.47$ pine, or 1.52 oak.

l being the length in feet of the longest unsupported part.

PRINCIPAL RAFTERS. When there is a king post.

$$D = \frac{L^2\,S}{B^3} \times 0.96 \text{ pine.}$$

When there are two queen posts.

$$D = \frac{L^2\,S}{B^3} \times 0.155 \text{ pine.}$$

STRAINING BEAM. Let its depth be to its thickness as 10 to 7.

$D = \sqrt{L\,S^{1/2}} \times 0.8$ pine.
$B = 0.7\,D.$

STRUTS AND BRACES. $D = \sqrt{L\,p^{1/2}} \times 0.9$ pine.
$B = 0.6\,D.$

p being the length in feet of the part of the principal rafter supported by the strut.

PURLINS. $D = \sqrt[4]{L^3\,C}$ pine, or $\times$ by 1.04 for oak.

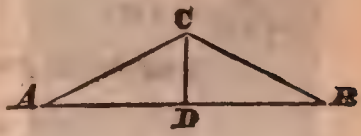
C being the distance in feet that the purlins are apart.

COMMON RAFTERS. $D = \frac{L}{B^{1/3}} \times 0.72$ pine, or 0.74 oak.

Two inches is the best thickness for common rafters, in which case $D = .571\,L$ for pine.

Strains on Trusses.

To find the strain on a simple truss:



Let S = half span A D.
R = rise, C D.
H = tension on the tie-rod.
T = thrust along the rafter, A C.
W = gross weight of the roof.

Then $H = \frac{W.S}{4.R}$

$$T = \sqrt{H^2 + \frac{W^2}{16}} = \frac{W}{4}\sqrt{\frac{S^2}{R^2} + 1}$$

There is no strain on the king bolt, C D, when the tie-rod is horizontal, except that arising from the tendency of the tie-rod to sag in the middle.

Resistance of the Ends of Tie-Beams, etc.

To Shearing from the Thrust of the Rafter.

L = breath of the beam.
H = horizontal thrust of rafter.
L = length of tie-beam from the end to the foot of the rafter.

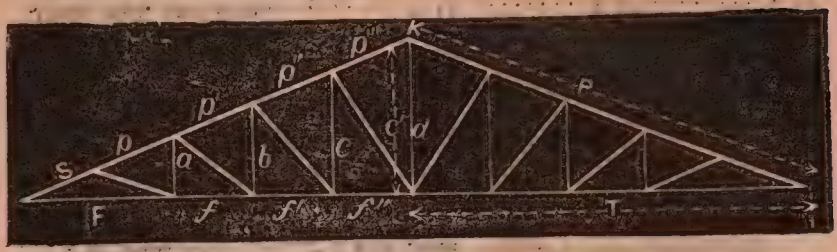
For oak, $L = \frac{H}{575\ B.}$ For pine $\frac{H}{150\ B.}$

Scarfed Joints in Tie-Beams.

Proportion of Length of Scarf to Depth of Beam.

	Without Bolts.	With Bolts.	Bolts and Indents.
Oak, ash, and elm	6 D	3 D	2 D
Pine	12 D	6 D	4 D

Strain on Roofs.



Rule for Strains on Iron Roofs.

Thick lines in compression; fine lines in tension.

P = Length of principal rafter.

R = Rise of roof from centre of tie-rod.

T = Length of ½ tie-rod.

L = Load on truss, including weight of framing.

N = Number of bays formed by the intersection of struts and ties with the principal rafters; in the diagram N = 10.

S = Strain at end of principal rafter.

F = Strain at end of tie-rod.

$$S = \frac{L\,P}{2\,R}$$

Strain at $p = S - \frac{S}{N}$

" at $p' = S - \frac{2\,S}{N}$

at $p'' = S - \frac{3\,S}{N}$

" at $p''' = S - \frac{4\,S}{N}$

$$F = \frac{L\,T}{2\,R}$$

Strain at $f = F - \frac{F}{N}$

" at $f' = F - \frac{2\,F}{N}$

" at $f'' = F - \frac{3\,F}{N}$

Strains on King and Queen Rods.

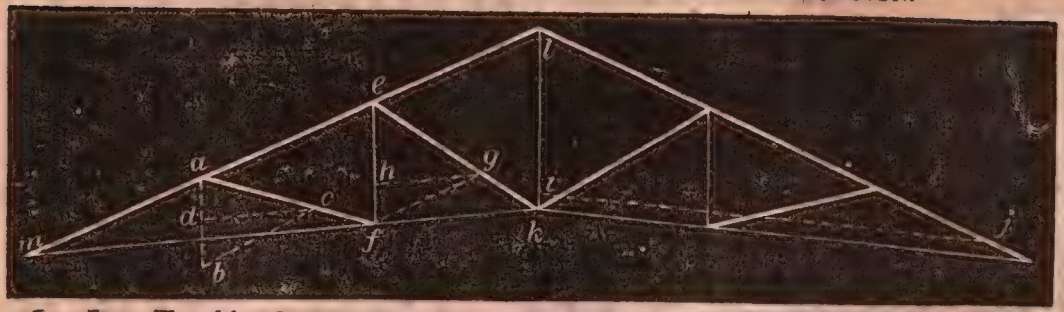
at $a = \frac{L}{2\,N}$

at $b = \frac{L}{N}$

at $c = \frac{1.5\,L}{N}$

at $d = \frac{4\,L}{N}$

Computation of Strains on Roofs by Construction.



Let L = Total load on truss. N = Number of bays formed by the intersection of the struts with the rafters = 6 in the diagram.

$$W = \frac{L}{N} = \frac{\text{Load}}{6} \text{ in the diagram.}$$

At *a* with any convenient scale lay off the perpendicular line *a b* = W on the scale of units; from *b* draw *b c* parallel to the rafter, intersecting the strut at *c*, and from *c* draw *c d* parallel with the tie-rod.

Again at *e* lay off with the same scale *e f* = W + *a d*, and draw as before *f g*, *g h* parallel with the rafter and tie-rod respectively.

Again at *l* lay off *l i* = W + *e h*, and from *i* draw *i j* parallel to the tie-rod until it intersects the rafter at *j*; the strains may be measured off with the scale as follows:

THRUST ON THE RAFTER.	STRAINS ON TIE-ROD.	THRUST ON STRUTS.	STRAINS ON KING AND QUEEN RODS.
Bet. *l* & *e* = *l j*.	Bet. *k* & *f* = *i j* + *g h*.	Bet. *e* & *k* = *e g*.	King = 2 *e h*.
" *e* & *a* = *l j* + *g f*.	" *f* & *m* = *i j* + *g h* + *c d*.	" *a* & *f* = *a c*.	Queen = *a d*.
" *a* & *m* = *l j* + *g f* + *c b*.			

Ramapo Wheel and Foundry Co.

Load on Roofs.

	Per square of 100 supl. feet.	Minimum slope.
Lead covering weighs	784 lbs.	4°
Zinc	168 "	4°
Corrugated iron	336 "	4°
Slates	840 to 1,008 "	25½° to 30°
Tiles	896 to 1,680 "	26½° to 30°
Boarding ¾ thick	290 "	25°
" 1½ "	580 "	25°
Timber framing for slated or tiled roofs	560 to 672 "	....
Additional load for pressure of wind	4,032 "	....
Hurricanes, say	8,960 "	....
Steepest angle of gothic roofs	....	60°

Corrugated Iron Roofing.

B Wire Gauge.	Size of Sheets.	Weight per square.	Square feet per ton.
No. 16	6×2 to 8×3 ft.	350 lbs.	800
" 18	6×2 to 8×3 "	258 "	1,000
" 20	6×2 to 8×3 "	204 "	1,250
" 22	6×2 to 7×2½ "	175 "	1,550
" 24	6×2 to 7×2½ "	136 "	1,880
" 26	6×2 to 7×2½ "	118 "	2,170

1-10th of the weight to be added for lappage.

Sheets should overlap about 6 inches, and be double rivetted at joints.

3 lbs. of rivets required per square of roofing.

Purlins should be six feet apart.

Curved roofs may be made up to 20 feet span without framing; tie-rods 12 feet apart.

Angles of Roofs.

Proportion of rise to span.	Angle.	Slope.	Proportion of rise to span.	Angle.	Slope.
1-6	18° 25″	3 to 1	⅔	53° 00″	¾ to 1
¼	26° 35″	2 to 1	¾	56° 20″	⅔ to 1
⅓	33° 42″	1½ to 1	1	63° 30″	½ to 1
½	45° 00″	1 to 1	..	.....	.....

Wooden Roofs.

Span in feet.	Principal.	Tie beam.	King posts.	Queen posts.	Small queens.	Straining beam.	Struts.
20	4×4	9× 4	4×4	..	..	..	3 ×3
25	5×4	10× 5	5×5	..	..	..	5 ×3
30	6×4	11× 6	6×6	..	..	..	6 ×3
35	5×4	11× 4	..	4×4	..	7×4	4 ×2
45	6×5	13× 6	..	6×6	..	7×6	5 ×3
50	8×6	13× 8	..	8×8	8×4	9×6	5 ×3
55	8×7	14× 9	..	9×8	9×4	10×6	5½×3
60	8×8	15×10	..	10×8	10×4	11×6	6 ×3

Slates.

Table of Sizes and Weights of Slates, exclusive of Laths.

Names.	Sizes.	Squares covered by 1,000.	Weight of 1,000, in lbs.	Weight per square.
Doubles	13× 6	2	1,680 lbs.	840 lbs.
Ladies.....	16× 8	4½	2,800 "	644 "
Countesses.....	20×10	7	4,480 "	644 "
Duchesses.....	24×12	10	6,720 "	672 "

Brickwork.

1 rod of brickwork.... = 272 superficial feet, 1½ bricks thick.
.... = 11⅓ cubic yards = 306 cubic feet.
.... = 4,350 bricks average work.
.... = 5,370 bricks, laid dry.

36 bricks flat, or 52 on edge..... = 1 yard paving.
No. of bricks in 1 cubic yard ..... = 384.
1 load of mortar..... = 1 cubic yard.
1 load of sand..... = 1 " "
1 bag of cement ..... = 3 bushels.
1 sack of cement..... = 5 "
1 cubic yard of brickwork requires about { 6½ cubic feet sand. 2½ " " lime.

Dimensions of Bricks.

Common brick..... 8 × 4¼ × 2½ ins. = 85 cubic ins.
Front " ..... 8¼ × 4½ × 2½ " = 92.8 "

Laid in Cement Occupy.

Common brick..... 8¼ × 4½ × 2¾ = 102 cubic ins.
Front " ..... 8½ × 4¾ × 2¾ = 111 "

15 common brick to a cubic foot of 8-inch wall, when laid.
22½ " " " 12 " "
30 " " " 16 " "
37½ " " " 20 " "

1,000 brick, closely stacked ..... = 56 cubic feet.
1,000 old brick, cleaned and loosely stacked... = 72 "

Bricks absorb one-fifteenth of their weight of water.

Bricklayers' hod will hold 20 bricks.
" " " ⅔ cubic foot of mortar.
" " " ½ bushel, nearly.

1 rod of brickwork requires 126 gallons of water to slack the lime and mix the mortar.

THE NUMBER OF BRICKS AND QUANTITY OF BRICKWORK IN WELLS AND CYLINDRICAL SEWERS, FOR EACH FOOT IN DEPTH OR LENGTH.

	HALF BRICK THICK.			ONE BRICK THICK.		
Diam. of Well.	NO. OF BRICKS. Laid Dry.	NO. OF BRICKS. In Mortar.	Cubic Feet of Brickwork.	NO. OF BRICKS. Laid Dry.	NO. OF BRICKS. In Mortar.	Cubic Feet of Brickwork.
1.0	28	23	1.6198	70	58	4.123
1.3	33	27	1.814	80	66	4.712
1.6	38	31	2 208	90	74	5.301
1.9	43	35	2.503	102	82	5.890
2.0	48	41.	2.797	112	92	6.479
2.3	53	44	3.092	122	100	7.068
2.6	58	48	3.387	132	108	7.657
3.0	68	57	3.976	154	126	8.835
3.6	79	65	4.565	174	142	10.013
4.0	89	73	5.154	194	159	11.191
4.6	100	82	5.743	214	176	12.370
5.0	110	90	6.332	234	192	13.548
5.6	120	98	6.921	254	209	14.726
6.0	130	107	7.510	276	226	15.904
6.6	140	115	8.099	296	242	17.082
7.0	150	123	8.688	316	260	18.260
7.6	160	131	9.277	336	276	19.438
8.0	170	140	9.866	358	292	20.616
8.6	180	148	10.455	378	308	21.794
9.0	191	156	11.044	398	326	22.972
10.0	212	174	12.222	438	360	25.329

Mortar, Cement, Etc.

Mortar.—1 of lime to 3 or 3½ of sharp river sand,

Or 1 of lime to 2 sand and 1 blacksmith's ashes, or coarsely ground coke.

Coarse Mortar.—1 of lime to 4 of coarse gravelly sand.

Concrete.—1 of lime to 4 of gravel and 2 of sand.

Hydraulic Mortar.—1 of blue lias lime to 2½ of burnt clay, ground together.

Beton.—1 of hydraulic mortar to 1½ of angular stones.

Cement.—1 of sand and 1 of cement. If great tenacity is required the cement should be used without sand.

Waterproof Mastic Cement.—1 of red lead to 5 of ground lime and 5 of sharp sand mixed with boiled oil.

Lime and sand, and cement and sand, lose about one-third of their bulk when made into mortar.

Lime, cement, and sand require to mix into mortar one-third of their bulk of water.

1 rod of brickwork requires 1 cubic yard lime, 3½ single loads of sand, or 36 bushels of cement and 36 bushels sharp sand.

1 barrel of cement is 5 struck bushels, weighs 336 pounds.

1 yard, or 9 superficial feet, 1½ brick thick, requires 2¼ bushels of cement.

1 yard, superficial, of pointing brickwork, in cement, requires one-eighth of a bushel.

When cement is used in winter, frost must be kept from the cement and stones or brick, heating both by artificial means. Frost destroys adhesive qualities of cement, if chilled at time of application.

Brown Mortar.

⅓ lime, ⅔ sand, and a small quantity of hair.

Plastering.

	1 in. thick.	¾ in. thick.	½ in. thick.
1 bushel of cement or 1.28 cubic feet will cover	1 1-7 s. yd.	1½ s. yd.	2¼ s. yd.
1 cement and 1 sand	2¼ "	3 "	4½ "
1 cement and 2 sand	3½ "	4½ "	6¾ "

1 cube yard of lime, 2 yards of sand, and 3 bushels of hair will cover..... } 75 yards sup. render and set, on brick, or 70 yards on lath.

Lath.

A plain lath is 1¼ in. wide by ¼ in. thick.
100 laths 5 feet long equal 1 bundle.
1 bundle of lath... } will cover 5 superficial yards.
500 3-penny nails... }

White-Washing.

(*See Receipt for do.*)

1½ cubic feet of lime will cover 100 yards, superficial... 1 coat.
2 " " " " " ... 2 "

Earthwork—Angles of Slopes.

Slopes	½ to 1	.....	= 63° 30′.
"	¾ " 1	.....	= 53° 00′.
"	1 " 1	.....	= 45° 00′.
"	1¼ " 1	.....	= 38° 40′.
"	1½ " 1	.....	= 33° 42′.
"	1¾ " 1	.....	= 29° 44′.
"	2 " 1	.....	= 26° 35′.
"	3 " 1	.....	= 18° 25′.
"	4 " 1	.....	= 14° 12′.

Natural Slopes of Earths, with Horizontal Line.

Gravel.....	Average	40°.
Dry sand.....	"	38°.
Sand.....	"	22°.
Vegetable earth.....	"	28°.
Compact earth.....	"	50°.
Shingle.....	"	39°.
Rubble.....	"	45°.
Clay, well drained.....	"	45°.
Clay, wet.....	"	16°.

Weight of Earths, Rocks, Etc.

Weight of cubic yard of	Sand	about	30 cwt.
" " "	Gravel	"	30 "
" " "	Mud	"	25 "
" " "	Marl	"	26 "
" " "	Clay	"	31 "
" " "	Chalk	"	36 "
" " "	Sandstone	"	39 "
" " "	Shale	"	40 "
" " "	Quartz	"	41 "
" " "	Granite	"	42 "
" " "	Trap	"	42 "
" " "	Slate	"	43 "

Quantity of Earths Equal to a Ton.

Sand river, as filled into carts	21	cubic feet.
" pit, " "	22	"
Gravel, coarse, " "	23	"
Marl, " "	28	"
Clay, stiff, " "	28	"
Chalk, in lumps, as filled into carts	29	"
Earth, mould, " "	33	"

Earth and clay increase in bulk ¼ when dug, but subside 1-5 in height, and derease ⅙ in bulk when formed into embankments.

Sand and gravel increase in bulk 1-12 when dug; sand subsides in embankments ¼ in height; gravel from 1-10 to 1-12, according to coarseness.

Rock increases ½ of its original bulk when excavated.

To find Area of Land in Cuttings and Embankments.

Rule—To find breadth required for the cutting or embankment, multiply depth of the cutting or height of embankment by the inclination of the slope.

To find Contents in Cubic Yards of Earthwork,

In Cuttings and Embankments, excluding the Slopes.

Add together the depths of the cutting or embankment in feet at each end, multiply the sum by width in feet, the length in chains, and by 1.233.

To find Contents in Cubic Yards of the Two Slopes.

Add together the depth of the cuttings at each end in feet, square the sum, and from it subtract the product obtained by multiplying the lengths together; multiply the remainder by the length in chains by the horizontal distance to 1 vertical rise in the slope, and by 0.8148.

Quantity of Excavations in Wells and Circular Shafts for each Foot in Depth.

Diameter of Excavation.		Quantity.	Diameter of Excavation.		Quantity.
Feet.	Ins.	Cubic yards.	Feet.	Ins.	Cubic yards.
3	0	.2618	6	6	1.2290
3	3	.3072	6	9	1.3254
3	6	.3563	7	0	1.4254
3	9	.4091	7	3	1.5290
4	0	.4654	7	6	1.6362
4	3	.5254	7	9	1.7472
4	6	.5890	8	0	1.8617
4	9	.6563	8	6	2.1017
5	0	.7272	9	0	2.3562
5	3	.8018	9	6	2.6253
5	6	.8799	10	0	2.9089
5	9	.9617	10	6	3.2070
6	0	1.0472	11	0	3.5198
6	3	1.1363	12	0	4.1888

Formulæ for Constructing Tables of Earthwork.

H and h = the heights of section in feet at each end of a chain length.

C = cubic contents of 1 chain length in YARDS.

S = slope.

C. P = central part.

The two slopes are taken separately from the central part—the former as the frustum of a pyramid 1 chain long, the latter the frustum of a wedge.

For Both Slopes.

Frustum of Pyramid $C = X \times (H^2 + h^2 + H\,h)$.

X = .204	in Slopes	¼ to 1	X = 1.223	in Slopes	1½ to 1
X = .408	"	½ to 1	X = 1.629	"	2 to 1
X = .815	"	1 to 1	X = 2.445	"	3 to 1

For Central Part.

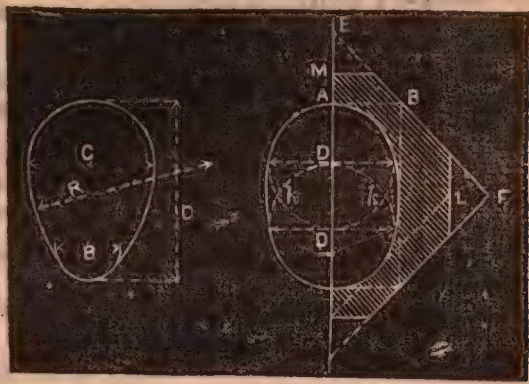
$C = k.\,(H + h)$ Frustum of Wedge.

k = 19.56	when base	= 16 feet	(Occupation roads).
k = 22.00	"	= 18 "	Single-line railway.
k = 24.45	"	= 20 "	Ditto.
k = 34.23	"	= 28 "	Public road.
k = 36.67	"	= 30 "	Double-line railway.
k = 40.34	"	= 33 "	Ditto.
k = 46.45	"	= 38 "	Turnpike road.
k = 1.2222 B	"	= B in feet.	

Prismoidal Formula.

$$\frac{[\text{Sum of areas of both ends} + (\text{Area of middle} \times 4)] \times \text{length}}{6}$$

Sewers.



Circular. $55\sqrt{x \times 2f} = v.$ $V \times A = C.$

x = area of sewer ÷ the wetted perimeter ; f = fall in feet per mile ; V = velocity of flow in feet per minute ; A = area of flow in square feet ; C = cubic feet of water delivered per minute.

Egg-Shaped.—Internal dimensions : B = diameter of bottom of sewer ; C = diameter of top ; R = radius of sides ; D = depth of sewer.

$$B = \frac{D}{3}; \quad C = \frac{2D}{3}; \quad R = D.$$

Under 6-feet culvert brickwork is generally 9 inches thick ; above 6 feet, and under 9 feet, should be 14 inches thick.

Oval Sewers.—Top and bottom of equal diameter. Diameter, D — 13-17ths of depth of culvert inside. The intersections of the top and bottom circles, k, k, form the centres for striking the curves which connect the top and bottom circles.

To Determine the Thickness of Brickwork.

Draw the lines A B, B C, respectively, parallel to the two axes of the culvert, and tangential to the curves ; their intersection at B gives the minimum thickness at that point.

Set off A E = A B join E B, and produce the line to F, and draw the line, M L, parallel to E F, and tangential to the curve ; the intersection of the line, M L, with the axes of the culvert, determine the minimum thickness at M and L.

The inclination of sewers should not be less than 1 in 240.

Ramapo Wheel and Foundry Co.

Cost of Railway Tunnels.

Location.	Per Cubic Yard.
Black Rock, U. S., greywacke slate	$6 60
Blaisley, France, lined	3 18
Blisworth, England, blue clay, lined	1 55
Blue Ridge, U. S.	4 00
England, free-stone, marble clay, etc., lined	3 46
Lehigh, U. S., hard granite	4 36
Schuylkill, U. S., slate	2 00
Union, U. S., slate	2 08

Shafts.

Blaisley Tunnel—clay, chalk, and loose earth; per yard in depth, $139 11. Deepest, 646 feet.

Black Rock—7 feet diameter, 139 feet deep; hard slate; per yard in depth, $79 50, or per cubic yard, $18 72.

Time required to drive the Black Rock Tunnel for 1,782.5 feet, was 2,387 turns, of 12 hours each.

Blasting.

In small blasts, 1 lb. of powder will loosen about 4½ tons.

In large blasts, 1 lb. of powder will loosen about 2½ tons.

50 to 60 lbs. of powder, inclosed in a resisting bag, hung against a gate or barrier, will demolish any ordinary construction.

One man can bore, with a bit 1 inch in diameter, from 50 to 100 inches per day of ten hours in granite, 300 to 400 inches in limestone.

Two strikers and a holder can bore, with a bit 2 inches in diameter, 10 feet in a rock of medium hardness.

Cost of Labor on Embankments.

(*Elwood Morris.*)

Single Horse and Cart.—Loaded cart in excavation and embankment can go 100 lineal feet and return in 1 minute, while moving. Time lost in loading, waiting, &c. = 4 minutes per load.

A medium laborer will load in a cart, in 10 hours, cubic yards of earth measured in the bank, as follows: *gravelly earth*, 10; *loam*, 13; *sandy earth*, 14.

Carts are loaded from banks: *Descending hauling*, ⅛ of a cubic yard, in bank; *level hauling*, 2-7 of a cubic yard, in bank; *ascending hauling*, ¼ of a cubic yard, in bank.

Loosening—In Loam.—A 3-horse plow will loosen 250 to 800 cubic yards in 10 hours; cost of do., from 1 to 8 cents per cubic yard, when wages = 105 cents per day.

Trimming and Bossing = 2 cents per cubic yard.

Scooping.—A scoop load = 1-10 of a cubic yard, in bank. The time lost in loading, unloading, and turning, per load = 1⅓ minutes. Time lost for every 70 feet of distance from excavation to bank and returning = 1 minute.

Hauling Stone.—A cart, with horses, over an ordinary road, will travel 1.1 miles per hour. A four-horse team will haul 25 to 36 cubic feet of limestone per load.

Time of unloading, loading, &c., averages 35 minutes per trip; cost of do., with horse-crane at quarry and unloading by hand, when labor = $1 25 per day and horse = 75, is 25 cents per perch = 24.75 cubic feet.

The work done by an animal is greatest when the velocity with which he moves is ⅛ of the greatest velocity he can move when unloaded, and the force then exerted is equal to .45 of the force the animal can exert at a dead pull.

Cost of Tunnels prior to 1855.

(*Major McClellan, U. S. A.*)

In soft sandstone, U. S., without lining, per lineal yard..	$88 00
In loose ground, thick lining, per lineal yard.....	710 00
Ordinary brick lining, including centering, per cubic yd.	8 50

Ramapo Wheel and Foundry Co.

Table of Culverts for Railways.

	Diameter.		Thickness of						Clear height inside.		Cube yds. in 1 lineal yard of Culvert.
			Arch.		Invert.		Sides.				
	ft.	in.	ft.	in.					ft.	in.	
Brickwork ...	1	6	0	9	Barrel						0.60
	2	0	0	9	Barrel						0.75
	3	0	0	9	0	9	1	2	3	3	1.60
	4	0	1	2	0	9	1	6	4	6	3.30
	5	0	1	2	0	9	1	10	5	6	4.70
	6	0	1	6	0	9	2	3	6	6	6.10
Rubble masonry with hammer-dressed arches.....	flat top 1	6	0	6	1	0	1	6	2	6	1.50
	flat top 2	0	0	9	1	0	2	0	3	0	2.00
	3	0	1	0	0	9	2	6	3	3	4.00
	5	0	1	0	1	0	3	0	5	6	6.70
	6	0	1	4	1	0	3	6	6	6	7.60

Reservoir Dams.

Width at top in high dams from 7 to 20 feet.
Width at top in low dams... = height.
Breast slopes..... = 3 to 1.
Back slopes..... = 2 to 1.
Height above surface of water not less than 3 feet 6 inches.

Masonry Dams.

Width at bottom..... = height × 0.7.
Width at middle..... = " × 0.5.
Width at top..... = " × 0.3.

Approximate Rules for Thickness of Arches.

Large Arches.

R = radius of arch at crown, in feet.
T = thickness of arch at crown, in feet.
S = span of arch, in feet.

In single arches..... $T = \sqrt{R \times .12}$

In viaducts of several arches $T = \sqrt{R \times .17}$

Table of the Thickness Required for the Crowns of Arches.

Radius of Curvature.	Stone Arches.	Brick Arches.	Radius of Curvature.	Stone Arches.	Brick Arches.	Radius of Curvature.	Stone Arches.	Brick Arches.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
2	.42	.56	14	1.12	1.50	60	2.33	3.10
2½	.47	.63	15	1.16	1.55	65	2.42	3.22
3	.52	.69	16	1.20	1.60	70	2 51	3.35
3½	.56	.75	17	1.24	1.65	75	2.60	3.46
4	.60	.80	18	1.27	1.70	80	2.68	3.58
4½	.64	.85	19	1.32	1.74	85	2.77	3.69
5	.67	.90	20	1.34	1.79	90	2.85	3.80
5½	.71	.94	22	1.41	1.88	95	2.92	3.90
6	.74	.98	24	1.47	1.96	100	3.00	4.00
7	.80	1.06	25	1.50	2 00	110	3.15	4.20
8	.85	1.13	30	1.64	2.19	120	3.29	4.38
9	.90	1.20	35	1.78	2.37	130	3.42	4.56
10	.95	1.26	40	1.90	2.53	140	3 55	4.73
11	1.00	1.33	45	2.01	2.68	150	3.67	4.90
12	1.04	1.38	50	2.12	2.83	160	3.80	5.06
13	1.08	1.44	55	2.22	2 97	170	4.18	5.58

TABLE OF THE MINIMUM THICKNESS OF ABUTMENTS FOR BRIDGE AND SIMILAR ARCHES OF 120°, WHERE THE DEPTH OF CROWN DOES NOT EXCEED 3 FEET.

Calculated from the Formula—

$$T = \sqrt{6\,R + \left(\frac{3}{2}\frac{R}{H}\right)^2} - \frac{3}{2}\frac{R}{H}$$

Radius of Arch.	Height of Abutment to Springing in Feet.				
	5	7.5	10	20	30
4.0 feet.	3.7	4.2	4.3	4.6	4.7
4.5 "	3.9	4.4	4.6	4.9	5.0
5.0 "	4.2	4.6	4.8	5.1	5.2
6.0 "	4.5	4.7	5.2	5.6	5.7
7.0 "	4.7	5.2	5.5	6.0	6.1
8.0 "	4.9	5.5	5.8	6.4	6.5
9.0 "	5.1	5.8	6.1	6.7	6.9
10.0 "	5.3	6.0	6.4	7.1	7.3
11.0 "	5.5	6.2	6.6	7.3	7.6
12.0 "	5.6	6.4	6.9	7.6	7.9
15.0 "	6.0	7.0	7.5	8.4	8.8
20.0 "	6.5	7.7	8.4	9.6	10.0
25.0 "	6.9	8.2	9.1	10.5	11.1
30.0 "	7.2	8.7	9.7	11.4	12.0
35.0 "	7.4	9.1	10.2	11.8	12.9
40.0 "	7.6	9.4	10.6	12.8	13.6
45.0 "	7.8	9.7	11.0	13.4	14.3
50.0 "	7.9	10.0	11.4	14.0	15.0

NOTE.—The abutments in the above table are assumed to be without counterforts or wing walls.

Piers for Trusses.

For piers supporting trusses not exerting any horizontal thrust, made of good masonry and upon a firm foundation, very little thickness is sufficient. The batter of piers from 10 to 20 feet high being one twelfth, and from 20 to 50 feet high one twenty-fourth. The following dimensions, all in feet, may be used:

Span of bridge.	Length of bridge seat.	Width of seat.
20 to 40	20	4.0
40 " 60	20	4.5
60 " 80	22	5.0
80 " 100	23	5.0
100 " 125	23	5.5
125 " 150	24	6.0
150 " 200	24	7.0

Retaining Walls.

E = Weight of earthwork per cube yard.
W = Weight of Wall, " "
H = Height of wall.
T = Thickness of wall at top.
T = H × Tabular No.

Batter of Wall.	E : W : : 4 : 5		E : W : : 1 : 1	
	Clay.	Sand.	Clay.	Sand.
1 in 4	.083	.029	.115	.054
1 " 5	.122	.065	.155	.092
1 " 6	.149	.092	.183	.118
1 " 8	.184	.125	.218	.153
1 " 12	.221	.160	.256	.189
Vertical.	.300	.239	.336	.267

Thickness of Walls of Buildings

Building Outer Walls.	Maximum Height of Wall.	Width of Footings.	Minimum Thickness of Walls in ins.						
			Ground Floor.	1st Floor.	2d.	3d.	4th	5th	6th
1st class dwelling.	85 ft.	38½ in.	21½	21½	17½	17½	17½	13	13
2d " " .	70 "	30½ "	17½	17½	17½	13	13	13	
3d " " .	52 "	30½ "	17½	13	13	13	13		
4th " " .	38 "	21½ "	13	13	8½	8½			
Party Walls.									
1st class dwelling.	....	38½ "	21½	21½	17½	17½	17½	13	13
2d " " .	.....	30½ "	17½	17½	..	13	13	13	
3d " " .	....	30½ "	17½	13	13	13	8½		
4th " " .	....	21½ "	13	8½	8½	8½			

If the walls are more than 70 feet long, the walls of the lower stories must be thickened by half a brick.

Warehouses.	Minimum Thickness of Wall.
1st class, for a height of 36 ft. from topmost ceiling.	17½ inches.
" " 40 feet lower	21½ "
" " 24 "	26 "
" for footings	43½ "
2d class, for a height of 22 ft. below topmost ceiling.	13 "
" " 36 feet lower	17½ "
" " 8 "	21½ "
" for footings	34½ "
3d class, for a height of 28 ft. below topmost ceiling.	13 "
" " 16 feet lower	17½ "
" for footings	30½ "
4th class, for a height of 9 ft. below topmost ceiling.	8½ "
" " 13 feet below.....	13 "
" for footings	21½ "

Ventilation.

Each person requires at least from 3 to 4 cube feet of air per minute. Ordinary windows allow about 8 cube feet a minute to pass.

Sleeping apartments require 1,000 cubic feet of space to each occupant.

Warming by Steam.

When the external temperature is 10° below freezing point, in order to maintain a temperature of 60°; or,

One superficial foot of steam pipe for each 6 superficial feet of glass in the windows; or,

One superficial foot of steam pipe for every 6 cube of air escaping for ventilation per minute; or,

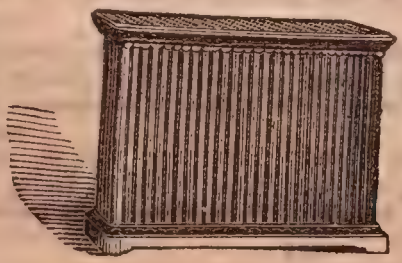
One superficial foot of steam pipe for every 120 feet of wall, roof, or ceiling; or,

One square foot of steam pipe to 80 cubic feet of space;

One cube foot of boiler is required for every 2,000 cube feet of space to be heated;

One horse-power boiler is sufficient for 50,000 cube feet of space. Steam should be about 212°.

Jos. Nason's Patent Radiator.



The cut represents radiator and section of pipe, invented by Jos. Nason, of New York, for heating by steam. By the use of the dividing sheet of iron in the pipe, shown in section, an upward and downward current of steam is caused in each pipe,

displacing all air in the pipe, and making one of the simplest as well as most scientific methods of making a steam radiator for warming purposes.

Gas.

Internal lights require 4 cubic feet of gas per hour, and external lights about 5 cubic feet per hour. Where large or Argand burners are used, from 6 to 10 cubic feet will be required.

The pressure with which gas is forced through pipes should seldom exceed 2½ inches of water at the works, or the leakage will exceed the advantages to be obtained from increased pressure.

A ton of coal yields about 10,000 cubic feet of gas.

Sound.

Velocity of sound in air	=	1,142	feet per second.
" " water	=	4,900	" "
" " iron	=	17,500	" "
" " copper	=	10,378	" "
" " wood	=	12,000	" "
	to	16,000	" "

Distance sounds may be heard on a still day.

Human voice	150 yards.
Rifle	5,300 "
Military band	5,200 "
Cannon	35,000 "

A Cheap Filter.

Any vessel with a small hole in the bottom, say a flower-pot, plugged (not tightly) at the bottom with sponge. A layer of coarsely powdered charcoal about one inch thick, is placed in the bottom of the pot, then another layer of sand of the same thickness, then pebbles, coarse gravel, and stones are placed on the whole. This forms an admirable filter, and one within the reach of the poorest.

Richmond Iron.

Glass.

Number of Lights per 50 Feet, or 1 Box.

Size.	Lts.	Size.	Lts.	Size.	Lts.	Size.	Lts.
6 × 8	150	12 × 14	43	14 × 24	22	20 × 24	15
7 × 9	114	12 × 15	41	15 × 15	32	20 × 25	14
8 × 10	90	12 × 16	38	15 × 16	30	20 × 26	14
8 × 11	82	12 × 17	35	15 × 18	27	20 × 28	13
8 × 12	75	12 × 18	33	15 × 20	24	21 × 27	13
9 × 10	80	12 × 19	32	15 × 21	23	22 × 24	14
9 × 11	73	12 × 20	32	15 × 22	22	22 × 26	13
9 × 12	67	12 × 21	29	15 × 24	20	22 × 28	12
9 × 13	61	12 × 22	28	16 × 16	28	24 × 28	11
9 × 14	57	12 × 23	26	16 × 17	26	24 × 30	10
9 × 15	53	12 × 24	25	16 × 18	25	24 × 32	9
9 × 16	50	13 × 14	39	16 × 20	23	25 × 30	10
10 × 10	72	13 × 15	37	16 × 21	21	26 × 36	8
10 × 12	60	13 × 16	35	16 × 22	20	28 × 34	8
10 × 13	55	13 × 17	33	16 × 24	19	30 × 40	6
10 × 14	51	13 × 18	31	17 × 17	25	31 × 36	6
10 × 15	48	13 × 19	29	17 × 18	24	31 × 40	6
10 × 16	45	13 × 20	27	17 × 20	21	31 × 42	6
10 × 17	42	13 × 21	26	17 × 22	19	32 × 42	5
10 × 18	40	13 × 22	25	17 × 24	18	32 × 44	5
11 × 11	59	13 × 24	23	18 × 18	22	33 × 45	5
11 × 12	55	14 × 14	37	18 × 20	20	34 × 46	5
11 × 13	50	14 × 15	34	18 × 22	18	30 × 52	4
11 × 14	47	14 × 16	32	18 × 24	17	32 × 56	4
11 × 15	44	14 × 17	30	19 × 19	20	36 × 58	3
11 × 16	41	14 × 18	29	19 × 20	19	38 × 58	3
11 × 17	39	14 × 19	27	19 × 22	17	40 × 60	3
11 × 18	36	14 × 20	26	19 × 24	16		
12 × 12	50	14 × 21	24	20 × 20	18		
12 × 13	46	14 × 22	23	20 × 22	16		

ILLUMINATION.

Gas, Lamps, and Candles, compared with Coal Gas.

Reports of Committee of Franklin Institute, and of A. Frye, Esq., M. D.

Lamp and Fluid.	Intensity of Light.	Ratio of Cost per Hour.	Light at Equal Cost.	Time of Burning 1 pint of Oil.	Relative Cost of Eq'l Lights.
				Hours.	$ cts.
Camphene	1.75	.57	3.08	9.31	.32
Carcel Sperm Oil, *max'm.*	2.15	1.22	1.8	6.32	.56
" " " *mean*	1.22	.86	1.35	9.87	.74
" " " *min'm.*	.69	.67	1.2	14.6	.83
" Lard Oil	.77	.76	.97	11.3	1.03
Gas	1	1	1	....	1
Semi-solar Sperm Oil	1.15	1.25	.93	6.75	1.07
Solar	1.76	1.09	1.55	8.42	.64

Candle.	Burns.	Intensity of Light.*	Light at Equal Cost.	Cost, with Equal Light.	Cost comp'd with Gas, for Equ'l Light.
	Hours.				
Diaphane	6.6	.7	.5	2.08	15.1
Palm Oil	6.6	.7	.77	1.32	10.5
Spermaceti Short 6's	8	.8	.54	2.16	16.2
Tallow Short 6's, single wick	6	.58	.85	1	7.5
" " double "	5.5	1	1	1.46	7.1
Wax Short 6's	9	.8	.61	1.96	14.4
" Long 4's	13	....	....	....	....

* Compared with fish-tail jet Edinburgh gas containing 12 per cent. of condensable matter, and consuming 1 cubic foot per hour.

The standard of intensity of light between different methods of illumination is a sperm candle, "short 6," burning 120 grains per hour.

DIMENSIONS, CONSUMPTION, AND COMPARATIVE INTENSITY OF LIGHT OF CANDLES.

CANDLE.	No. in a pound.	Diameter.	Length.	C'nsumption per hour.	Light comp'd with Carcel.
		Inches.	Inches.	Grains.	
Wax	3	1	12		
"	3	⅞	15	135	.09
"	6	.8	9		
Spermaceti..	3	.9	15		
" ..	4	.8	13½	156	.09
" ..	6	.84	8½		
Tallow.....	3	1	12½		
"	3	.9	15	204	.06 to .08
"	4	.8	13¾		

The illuminating power of coal gas varies from 4.4 to 1.6 times that of a tallow candle 6 to a pound, the consumption being from 2.3 to 1.5 cubic feet per hour; specific gravity from .58 to .42.

The higher a flame from a burner, the greater the intensity of the light, most effective height being 5 inches.

RELATIVE INTENSITY OF LIGHT FROM DIFFERENT CANDLES.

CANDLES.	Gas = 1.	Burned during Flow of 1,000 Cubic ft. of Gas.	Giving Light = to 1,000 Cubic ft. of Gas.	Am't Burned for Equal Light.
		Lbs.	Lbs.	
Paraffine ...	.098	3.5	35.5	103
Sperm	.095	3.9	41.1	120
Adamantine.	.108	5.1	47.2	137
Tallow.....	.074	5.1	53.8	155

Ramapo Wheel and Foundry Co.

Relative Intensity, Consumption, and Cost of Various Modes of Illumination.

Oil at 11 cts. per lb.; Tallow at 14 cts. per lb.; Wax at 52 cts. per lb.; Stearine at 32 cts. per lb.; 100 cubic feet coal gas at 14 cts.; 100 cubic feet oil gas at 52 cts.

Illuminator.	Intensity.	Consumption per Hour.	Illuminat'n. Carcel Lam.p = 100.	Actual Cost per Hour, in cents.	Cost per Hr. for Equal Intensity, in cents.
Carcel Lamp....	100	42	100	.87	.87
Lamp, with inverted Reservoir	90	43	57.8	.89	.99
Astral Lamp....	31	26.7	48.7	.56	1.78
Petticoat "	6.65	8	33.6	.16	2.49
Wax Candle, 6's.	14.6	9.6	61.6	.92	6.31
Stearine, 5's....	14.4	9.3	66.6	.59	4.13
Tallow, 6's.....	10.7	8 5	54	.25	2.34
Sperm, 6's.....	16.	8.8	67.5	.89	5.7
		Cubic Ft.			
Coal Gas	127	8.7	....	1.16	.91
Oil Gas	127	2.4	....	1.26	.73

1,000 cubic feet of 13-candle coal gas is equal to 7.5 gallons sperm oil, 52.9 lbs. mould candles, and 44.6 lbs. sperm candles. 1 cubic foot of gas, from a jet 1-33 of an inch in diameter, and height of flame 4 inches, will burn for 65 minutes. In Winter the average duration of internal lights per day is 5.08 hours; in Summer, 2 83; Spring, 3.41; Fall, 4.16. Fish-tail burners consume 4 to 5 cubic feet of gas per hour.

Intensity of Light, with Equal Volumes of Gas from Different Burners.

Burners.	Expen. in cubic ft. per hr.				Almost effective height of Flame.
	1	2	3	4	
Single jet, 1 foot = candles	2.6	..	..	..	100
Fist-tail, No. 3, = 1 ft. "	3.5	4.	4.2	..	138
Bat's wing, = 1 ft. "	3.	4.1	4.3	4.5	135
Argand, 16 holes = 1 ft. "	.32	1.9	3.3	3.8	...
" 28 " = 1 ft. "	.34	2.3	3.5	5.8	183

Services for Gas Lamps.

2 lamps,	40 feet	from main,	require	.....	⅜	bore	of	pipe.
4 "	40	"	"	"	½	"	"	
6 "	50	"	"	"	⅝	"	"	
10 "	100	"	"	"	¾	"	"	
15 "	130	"	"	"	1	"	"	
20 "	150	"	"	"	1¼	"	"	
25 "	180	"	"	"	1½	"	"	
30 "	200	"	"	"	1¾	"	"	

Diameter and Extreme Length of Tubing for Given Number of Burners.

No. of Burners.	Diameter of Pipe.	Length.	Capacity of Meters in Lights.	No. of Burners.
	Inches.	Feet.		
1	¼	6	3 =	6
3	⅜	20	5 =	10
6	½	30	10 =	20
12	⅝	40	20 =	40
20	¾	50	30 =	60
35	1	70	45 =	90
60	1¼	100	60 =	120
100	1½	150	100 =	200
200	2	200	... =	...

Loss of Light by Glass Globes.

Clear glass, 12 per cent.; half ground, 35 per cent.; full ground, 40 per cent.

Loss of Light by Use of Shades.—(*F. H. Storer.*)

Glass, etc.	Thickness.	Loss.	Glass, etc.	Thickness.	Loss.
	Ins.	Pr Ct.		Ins.	Pr Ct.
American Enamelled	1-16	51.23	Window, d'ble, Eng.	1-8	9.39
Crown.....	1-8	13.08	" " Ger..	1-8	13.
Crystal Plate	1-8	8.61	" single, Ger..	1-16	4.27
English	1-8	6.15	" " ground	1-16	65.75
Porcelain Transp'cy.	1-3	97.68	" green.....	1-16	81.95

Ramapo Wheel and Foundry Co.

Glue.

To Dry Rapidly and to Resist Moisture.

1 pound best glue.
4 ounces dry white lead.
3 ounces prepared chalk.
3 pints water.

To be boiled and well mixed.

Number of Nails per Pound.

Title.	Size.	Number.
3-penny	1 inch.	557 nails.
4 "	1¼ "	353 "
5 "	1¾ "	232 "
6 "	2 "	167 "
7 "	2¼ "	141 "
8 "	2½ "	101 "
10 "	2¾ "	68 "
12 "	3 "	54 "
20 "	3½ "	34 "
30 "	4 "	26 "
40 "	4½ "	20 "

Spikes.

Boat.

No. 4....1-4 in....13 to 1 lb.
No. 5....5-16 in.... 8 "
No. 6....3-8 in.... 5 "
No. 7....5-8 in.... 4 "

Ship.

No. 4....5-16 in....8 to 1 lb.
No. 5....3-8 in....6 "
No. 6....3 8 in....5 "
No. 7....3-8 in....3½ "
No. 8....3-8 in....3 "
No. 9....9-16 in....2 "
No. 10....9-16 in....1½ "

Painting.

1 gallon	priming color	will	cover	50	superficial	yards.
1 "	white zinc	"	"	50	"	"
1 "	white paint	"	"	44	"	"
1 "	lead color	"	"	50	"	"
1 "	black paint	"	"	50	"	"
1 "	stone color	"	"	44	"	"
1 "	yellow paint	"	"	44	"	"
1 "	blue color	"	"	45	"	"
1 "	green paint	"	"	45	"	"
1 gal.	bright emer. green	"	"	25	"	"
1 gal.	bronze green	"	"	45	"	"

One pound of paint will cover about four superficial yards the first coat, and about six yards each additional coat.

One pound of putty for stopping every twenty yards.

One gallon of tar, and one pound of pitch, will cover twelve yards superficial the first coat, and seventeen yards each additional coat.

Paints, Lackers, Etc. (Ordnance Manual.)

The proportions are for 100 *parts by weight of prepared color.*

1 gallon linseed oil	weighs	7.45 lbs.
1 " spirits turpentine	"	7.00 "

Boiled Oil.

Raw linseed oil	103.
Copperas	3.15
Litharge	6.3

Put the litharge and copperas in a cloth bag and suspend in the middle of the kettle. Boil the oil four hours and a half over a slow fire, then let it stand and deposit the sediment.

Drynings.

Mixture of copperas and litharge taken from the boiled oil	60.
Spirits turpentine	56.
Boiled oil	2.

Putty.

Spanish whiting, pulverized	81.6
Boiled oil	20.4

Made into a stiff paste. If not intended for immediate use, raw oil should be used.

White Paint.

	Inside work.	Outside work.
White lead, ground in oil	80.	80.
Boiled oil	14.5	9.
Raw oil	...	9.
Spirits turpentine	8.	4.

New wood-work requires 1 lb. to the square yard for three coats.

Lead Color.

White lead, ground in oil	75.
Lamp black	1.
Boiled linseed oil	23.
Litharge	0.5
Japan varnish	0.5
Spirits turpentine	2.5

Lamp black and litharge are ground separately with oil, then stirred into the white lead and oil.

Black Paint.

Lamp black	28.	Linseed oil, boiled	73
Litharge	1.	Spirits turpentine	1.
Japan varnish	1.		

Gray or Stone Color. (*For Buildings.*)

White lead, in oil	78.
Boiled oil	9.5
Raw oil	9.5
Spirits turpentine	3.
Turkey amber	0.5
Lamp black	0.25

One square yard of new brick-work requires for two coats, 1.1 lb.; for three coats, 1.5 lb.

Cream Color. (*For Buildings.*)

	1st coat.	2d coat.
White lead, in oil	66.66	70.
French yellow	3.33	3.33
Japan varnish	1.33	1.33
Raw oil	28.00	24.5
Spirits turpentine	2.25	2.25

One square yard of new brick-work requires for first coat, 0.75 lbs.; for second, 0.3 lbs.

Paint for Tarpaulins.

1st. Olive.—	Liquid, olive color	100.
	Beeswax	6.
	Spirits turpentine	6.

Dissolve the beeswax in spirits of turpentine, with a gentle heat, and mix the paint warm.

2d. Add 12 ounces beeswax to 1 gallon of linseed oil, boil it two hours; prime the cloth with this mixture, and use it in place of boiled oil, for mixing the paint.

Asphalte Flooring.

8 lbs. of asphalte composition will cover 1 superficial foot, ¾-inch thick.

Cement to Resist Fire and Water, and Harden Quickly.

2 parts finely sifted unoxidised iron filings.
1 part, perfectly dry, finely powdered loam.
Knead the mixture with strong vinegar into a homogeneous plastic mass, to be used as soon as made.

Cheap Paint for Sheds and Fences.

6 lbs. melted pitch, 1 pint linseed oil, 1 pound brick dust, or yellow ochre.

CONSTRUCTION.

Strength of Materials of Construction.

Materials are exposed to four different classes of strains:

1st. May be torn asunder, in direction of length; power to resist which is called cohesive strength, or tenacity.
2d. May be crushed as in columns.
3d. May be broken across, as in beams, the strength to resist which is called lateral or transverse strength.
4th. May be twisted, as in axles, screws, etc.

The transverse strength of rectangular beams, etc., is inversely as their length, and directly as their breadths, and square of their depths; and if cylindrical, as the cubes of their diameters; that is, if a beam 6 feet long, 2 inches broad, and 4 inches deep, can carry 2,000 lbs., another beam of the same material 12 feet long, 2 inches broad, and 4 inches deep, will only carry 1,000, being inversely as their lengths.

Again, if a beam 6 feet long, 2 inches broad, and 4 inches deep, can support a weight of 2,000 lbs., another beam of the same material, 6 feet long, 4 inches broad, and 4 inches deep, will support 4,000 lbs., but a beam 6 feet long, 2 inches wide, and 8 inches deep, will support 8,000 lbs., being as the square of their depths.

The ultimate resistance in pounds per square inch of section of various materials for construction, are as below:

Name of the Material.	Resistance to Extension.	Resistance to Compression.	Tensile Strength in Practice.	Comp. Strength in Practice.
White pine....	10,000	6,000	2,000	1,200
White oak.....	15,000	7,500	3,000	1,500
Rock elm	16,000	8,011	3,200	1,602
Wrought-iron..	60,000	50,000	12,000	10,000
Cast-iron	20,000	100,000	4,000	20,000

In practice, the fifth part of the above strengths is all that should be employed, as given in the third and fourth columns. The dimensions of pieces of wood or iron, however used to resist compression, are often determined more with regard to the power of the piece to resist bending or bulging, than to resist crushing, as in posts.

Rods, Nuts, and Washers.

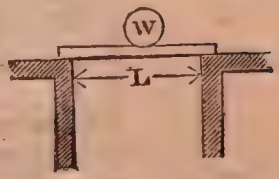
Diameter of Rod.	Strength.	Weight per Foot.	Square Nut.		Screw Threads per inch.
		Lbs.	Side.	Depth.	
½	2,280	0.66	1¼	¾	12
¾	5,000	1.49	1½	⅞	10
1	9,000	2.65	2	1	8
1¼	14,040	4.17	2¼	1¼	7
1½	20,280	5.97	2¾	1½	6
1¾	27,480	8.18	3	1¾	5
2	36,000	10.62	3½	1⅞	4.5

In the above, column 1 gives the diameter of rod in inches; column 2 the strain to which it may safely be subjected, being at the rate of 12,000 lbs. per square inch; column 3 the weight

per lineal foot; columns 4 and 5 the side and depth of a square nut equal in strength to the rod; and column 8 the number of screw threads per inch in length.

Transverse Strength of Beams in General.

(*Hurst.*)



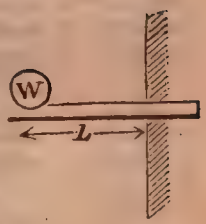
Supported at the ends and loaded in the middle.

b = breadth in inches.
d = depth in inches.
L = length in feet.
W = breaking weight in cwts.

$$W = C\frac{b\,d^2}{4}$$

C being the weights in cwts., required to fracture a bar 1 inch square and 1 foot long.

C = 25 wrought-iron.
" = 18 cast-iron.
" = 8 brass.
" = 7 zinc.
" = 7 teak.
" = 5 ash and oak.
" = 5 pitch pine.
" = 4 white pine, fir, and beech.
" = 3 elm and larch.



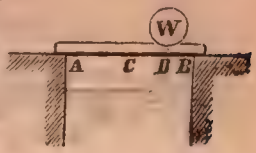
If the beam is fixed at one end and loaded in the middle, take 1¼ W.

If the beam is fixed at both ends and loaded in middle, take 1½ W.

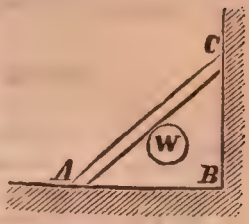
If fixed at one end, and loaded at the other, take ¼ W.

In all cases when the load is uniformly distributed, double the weight will be required to cause fracture, that would, if placed in the middle.

If the load is applied at any other point, as at D, the breaking weight will be equal to the square of half the length of A B, multiplied by the breaking weight in the middle, and divided by the product of the distance A D and D B from each end. When a beam is continued over three or more points, and the load uniformly distributed, it will be sufficient to take the part between any two points of support, *as a beam fixed at both ends.* If some of the parts have a greater load than the others, it will be near enough in practice to take the parts so loaded, *as supported on the ends only.*



Inclined beams supported at the ends have their breaking weight equal to that of the same beam when horizontal, multiplied by the length, A C, and divided by the horizontal distance, A B.



When the beam is CYLINDRICAL, take the cube of the diameter instead of the breadth and square of the depth, and five-sixths of W thus found will equal breaking weight.

For HOLLOW CYLINDERS, take the *difference* of the cubes of external and internal diameters, and proceed as for solid cylinders. The foregoing formulæ for the breaking weight of beams are only applicable when the breadth of the beam is to its depth as about 5 to 7, or where they can be kept from twisting by proper struts.

Solid cylinder of cast-iron.....$W = 12 \frac{D^3}{L}$

Solid cylinder of wrought-iron.....$W = 18 \frac{D^3}{L}$

Hollow cylinder of cast-iron.....$W = 12 \frac{D^3 - d^3}{L}$

Hollow cylinder of wrought-iron.....$W = 18 \frac{D^3 - d^3}{L}$

Wood is from 7 to 20 times stronger transversely than longitudinally; it becomes stronger both ways when dry.

When one beam is let in, at an inclination, to the depth of another, so as to bear in the direction of the fibres of the beam that is cut, the depth of the cut at *right angles* to the fibre should not be more than one-fifth of the length of the piece, the fibres of which, by their cohesion, resist the pressure.

Cohesive Strength of Tie-Bars, Suspension Rods, etc.

Breaking weight in tons, equal area of section of rod in square inches, multiplied by cohesive force per square inch in tons.

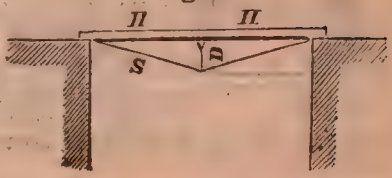
Cohesive strength of	steel	=	50	tons.
" "	wrought-iron		20	"
" "	cast-iron		7	"
" "	wrought copper		14	"
" "	cast brass		8	"
" "	lead		0.75	"
" "	boxwood		10	"
" "	ash		8	"
" "	beech		5.5	"
" "	oak		5.5	"
" "	" seasoned		6.0	"
" "	pitch pine		6.0	"
" "	chestnut		5	"

In use, take ¼ of the above as breaking weight.

Beams of Wood Trussed with Wrought-Iron.

L = length in feet } Measured from the points of intersec-
D = depth in feet } tion of stay, tension rod, and top beam.
W = load in tons uniformly distributed.
H = horizontal thrust on beams in tons.
S = strain on inclined part of tension rod in tons.

Fig. 1.



$$H = \frac{W\,L}{8\,D}$$

$$S = \sqrt{H^2 + \frac{W^2}{16}}$$

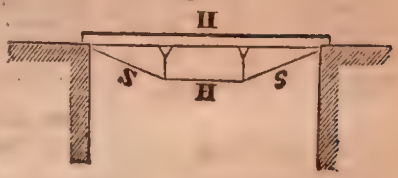
When the truss has more than one stay—

H will be as in Fig. 1, L and D being the same; the tensile strain on the horizontal part of the tie-rod will also = H.

For the strain on the inclined tie we have—

$$S = \frac{W}{8\,D}\sqrt{L^2 + n^2\,D^2}$$

Fig. 2.



n being the number of times the horizontal distance between the pier and the nearest stay is contained in L; it equals 2 in fig. 1 and 3 in fig. 2.

When the load is placed in the middle, the strain H will be doubled.

When a load = W is placed on each of the stays—

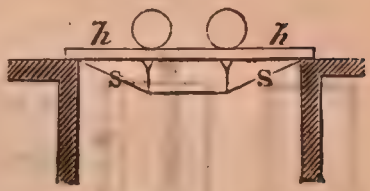
Let l = the distance of each loaded stay from the nearest pier.

D = depth of truss as before.

h = horizontal thrust on the part next the pier.

s = the tension on each of the inclined ties.

Fig. 3.



$$\text{Then } h = \frac{W\,l}{D} \qquad S = \sqrt{h^2 + W^2}$$

To resist the strains s s with safety, allow one inch of sectional area in the tie-rod for every 5 tons of strain.

The stay D being in compression, should be calculated as a column capable of supporting the load, if in the middle, or one-half if distributed.

The top beam, though in compression from the strain H, should be capable of supporting the load between the stays as a beam exposed to transverse strain, the rules for obtaining which have been given.

Stiffness of Girders of Wood.

10 feet apart in floors.

B = Breadth in inches.
D = Depth in inches.
L = Length in feet.

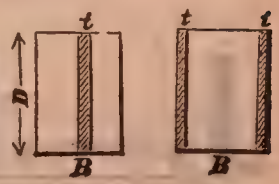
$$D = \sqrt[3]{\frac{L^2}{B}} \times 4.2 \text{ for pine, by } 4.34 \text{ oak.}$$

$$B = \frac{L^2}{D^3} \times 74 \text{ for pine, or } 82 \text{ oak.}$$

To obtain maximum stiffness B should $= \frac{5}{7}$ D.

Girders of Wood, with Wrought-Iron Flitches.

B = Breadth of wood in inches.
D = Depth in inches.
t = Thickness of iron flitch in inches.
L = Length of bearing in feet.
W = Breaking weight in cwts. in the middle.



$$W = \frac{D^2}{L}(C\,B + 30\,t)$$

C = 4.0 teak.
= 3.0 oak.
= 2.5 pine.
= 2.0 elm.

Safe Load in Structures, including Weight of Structure.

In cast-iron columns	= ¼	breaking	weight.
Wrought-iron structures	= ¼	"	"
In cast-iron girders for tanks	= ¼	"	"
In cast-iron for bridges and floors	= ⅙	"	"
In timber	= 1-10	"	"
Stone and bricks	= ⅛	"	"

Relative Strength of Beams or Girders.

Supported at one end and loaded at the other..... = 1
" " " load distributed..... = 2
" both ends and load at centre..... = 4
" " " distributed..... = 8"
Firmly fixed at both ends..... = 16"

or conversely.

Supported at both ends and load distributed..... = 1
" " " at centre..... = ½
" one end, load distributed..... = ¼
" " load at the other end..... = ⅛

Strength of Iron.

Name.	Description.	Breaking Weight.				
		Specific Gravity.	Tensile.	Transverse.	Torsion.	Crushing.
Stockton-on-Tees..	No. 3 Pig...	7.135	22,271	6,932	6,305	87,063
Hermatite Co.....	No. 2 Pig...	7.214	17,958	5,538	5,299	82,265
Weardale Co.....	No. 3 Pig...	7.158	21,859	7,374	6,369	93,989
Butterley Co.....	No. 3 Pig...	7.126	23,265	6,692	6,940	91,661
Lord Ward's.....	No. 3 Pig...	7.052	25,872	6,992	6,833	94,077
Blaen-Avon.....	Cold Blast No. 1...	7.137	25,456	8,873	5,966	95,775
Dr. Price's.....	Imp'ved (P.)	7.259	28,960	9,120		
Mean of 51 samples	.....	7.140	23.257	7,102	6,056	91,061

The breaking weights are in lbs. per square inch.

Transverse breaking weight, the strain necessary to break a bar 1 inch square projecting horizontally one inch beyond the point of support, the weight being applied at the outer end.—*British Ordnance Experiments.*

Tensile Strength of Richmond Iron.

No. 3 Pig.... 28,442 to 30,000 | Re-melted.... 35,000 to 40,699

Tenacity of Wrought-Iron.

	Lbs. per square in.
Lancashire bar	57,000
Low Moor bar	64,000
Staffordshire bar	59,000
" plates	50,000 to 60,000
Yorkshire plates	52,000 to 58,000
Bessemer iron, cast	41,000
" plates	70,000

Cast-Iron Girders.

D = depth of girder in inches.
A = area of bottom flange in inches.
S = span in inches.
W = breaking weight in tons.

Supported at both ends with load on centre.... $W = \frac{25\ A.\ D.}{S}$

Supported at both ends with load distributed... $W = \frac{50\ A.\ D.}{S}$

If the depth = 1-12 of the span, $W = A\ 4.17$ } where weight is
If the depth = 1-10 of the span, $W = A \times 5$ } distributed.

Area of top flange if the load is applied on the top..... $= \frac{A}{3}$

Area of top flange if the load is applied on bottom flange. $= \frac{A}{2}$

Depth at the ends may equal..... $\frac{2\ D}{3}$

Safe deflection 1-40th inch for each foot of span, under a test load of ⅓d of the breaking weight.

Strength of Sections of Wrought-Iron Beams,

For Sustaining with Safety a Load Uniformly Distributed.

(Nystrom.)

Distance between Supports.	COMPOUND GIRDERS.			SOLID ROLLED BEAMS.					
	18 ins. High.	15 ins. High.	12 ins. High.	15 ins. High.	12 ins. High.	9 ins. High.	9 ins. High.	7 ins. High.	6 ins. High.
	W'ght 78 lbs. per ft.	W'ght 71 lbs. per ft.	W'ght 59.5 lbs per ft.	W'ght 47.8 lbs per ft.	W'ght 40 lbs. per ft.	W'ght 30 lbs. per ft.	W'ght 29.3 lbs per ft.	Wght 20 lbs per ft.	Wght 13.3 per ft.
In ft.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
10	80.00	66.67	53.33	49.00	29.60	30.80	16.80	8.40	4.80
12	66.66	55.56	44.44	40.83	24.66	25.69	14.00	7.00	4.00
14	57.14	47.61	38.09	35.00	21.14	22.05	12.00	6.00	3.43*
16	50.00	41.67	33.33	30.63	18.50	19.25	10.50	5.25	3.00
18	44.44	37.04	28.52	27.22	16.44	17.11	9.33	4.66	2.66
20	40.00	33.33	26.66	24.50	14.80	15.40	8.40	4.20	2.40
22	36.36	30.30	24.24	22.27	13.45	14.00	7.63	3.81*	2.18
24	33.33	27.77	22.22	20.42	12.33	12.85	7.00	3.50	2.00
26	30.77	25.64	20.05	18.85	11.38	11.87	6.46	3.23	1.84
28	28.57	23.80	19.05	17.50	10.57	11.00	6.00*	3.00	1.71
30	26.66	22.22	17.77	16.33	9.86	10.26	5.60	2.80	1.60
32	25.00	20.83	16.66	15.31	9.25	9.62	5.25	2.62	1.50
34	23.53	19.60	15.65	14.41	8.71*	9 06*	4.94	2.47	1 40
36	22.22	18.52	14.26	13.61	8.22	8.55	4.66	2.33	1.33
38	21.05	17.37	14 00	12.90*	7.80	8.11	4.42	2.21	1.26
40	20.00	16.66	13.33	12.25	7.40	7.70	4.20	2.10	1.20
42	19.05	15.87	12.70*	11.67	7.05	7.34	4.00	2.00	1.14
44	18.18	15.15	12.12	11.13	6.72	7.00	3.81	1.91	1.09
46	17.37	14.48*	11.44	10.66	6.43	6.70	3.65	1.83	1.04
48	16.66	13.88	11.11	10.21	6.16	6.42	3.50	1.75	1.00
50	16.00*	13.33	10.66	9.80	5.92	6.16	3.36	1.68	.96

* Span being given, the star denotes an approximation to beam to be used.

The table gives the weight in tons, sustained by the several kinds of beams; the weight uniformly distributed over them as on a floor, being 9 tons per square inch of that part of the metal subjected to a crushing force. Under these weights the beams are within the limits of perfect elasticity, and the deflections are in proportion to the load.

If the entire weight is to be supported in the centre, divide the figures in table by 2.

If at any other point, weight at centre is to weight at any other point as the square of half the beam is to the rectangle of the two parts from where the weight is applied.

Wrought Iron Girders.

D = Depth of girder, in inches.
A = Area of bottom flange, in inches.
S = Span, inches.
W = Breaking weight, in tons.

$$\frac{80\ A.D.}{S} = W \left\{ \begin{array}{l} \text{for girders supported at both ends, load in} \\ \quad \text{centre.} \end{array} \right.$$

$$\frac{160\ A.D.}{S} = W \left\{ \begin{array}{l} \text{for girders supported at both ends, and load} \\ \quad \text{distributed.} \end{array} \right.$$

Area of top flange = 1.18 A.

$$\text{Depth} = \frac{S}{13} \text{ or } \frac{S}{12}$$

Rivets ¾ and 1″ diameter $\left\{ \begin{array}{l} 3'' \text{ apart in the top.} \\ 4'' \text{ apart in bottom.} \end{array} \right.$

$$\left. \begin{array}{l} \text{If } D = \frac{S}{12} \text{ then } W = 13.3\ A. \\ \text{If } D = \frac{S}{10} \text{ then } W = 16.\ A. \end{array} \right\} \text{Weight distributed.}$$

Wrought Iron Beams and Girders.

Cooper, Hewitt & Co., New York.

The resistance of wrought-iron to crushing being less than its resistance to tearing, the effective area of the parts of a beam subjected to the former strain, should be at least equal to that of the corresponding parts subjected to the latter strain. The proportions of a wrought-iron beam therefore differ essentially from those of a cast-iron beam, the resistance of cast-iron to crushing being five times its resistance to tearing.

The ultimate or breaking resistance of wrought-iron to direct crushing is from 36,000 to 40,000 lbs., and to tearing from 50,000 to 60,000 lbs. per square inch. Its resistance, however, to either strain for any load that can be safely applied in practice is equal —that is to say, the same force will produce an equal amount of compression and extension.

In RIVETED GIRDERS the rivet holes diminish by so much the *effective* area of the extended parts, but not that of the compressed parts. In many cases, also, as in fire-proof floors, the filling between the beams aids materially in resisting compressive forces. For these reasons the plates or flanges of the upper and lower sides of wrought-iron beams or girders of moderate dimensions, are usually made of equal areas.

The ordinary forms used are—

1 2

3 4 5 6 7 8

No. 1 is a solid rolled beam.

Nos. 4 and 6 are made by riveting the vertical plates to two T or channel bars.

Nos. 2, 3, 7, 8, combinations of plates and angle bars.

No. 5. The top and bottom plates are connected at intervals by studs, which are riveted into the horizontal plates, and the vertical plates are riveted to the studs, one on each side.

The same formulæ are applicable to all the forms, except that the box girders have more lateral stiffness, and that for solid rolled beams the whole area is effective, while in the riveted girders the rivet holes diminish the effective area to resist extension.

Formula. $$W = \frac{\left(A + \frac{a}{6}\right)d}{L} \times \frac{2}{3} f$$

W = The uniformly distributed load for a beam supported at both ends.

L = Distance, in feet, between the supports.

d = The depth of the beam, in inches.

A = The effective area, in square inches, of the bottom plates, bars, or flanges, the area of the top plates, bars, or flanges, being at least equal to that of the bottom plates.

a = The area, in square inches, of the vertical plates; if more than one, of both. If the vertical plates are not the full depth of the girder, as in figures 3, 4, 5, 7, the area, a, is estimated as if the plates were full depth, and the excess over the actual areas deducted from A.

f = The resistance, per square inch of section, exerted by the fibres of the beam furthest from the neutral axis, at the cross section of greatest strain, with the load W on the beam.

[NOTE.—It has been found by experiments on beams that the breaking strength does not exactly correspond with that deduced from the resistance to direct crushing and tearing; for the breaking load for beams and girders, f, may be taken at 45,000 lbs., and for the safe load at 15,000 lbs.]

The load W will be the breaking or safe distributed load, according as the value of f is taken, and will be given in the same unit of weight as that in which f is estimated. For the safe working distributed load in net tons, taking f at 7½ tons, the formula becomes

$$W = \frac{5\left(A + \frac{a}{6}\right)d}{L}$$

For figure 6, using channel bars, each 54 lbs. per yard, 6 ins. wide, 2¾ ins. deep, base ½ in. thick, flanges ½ in. thick.

$$W = \frac{(24 + 5\text{-}6\ a)\ d}{L}$$

Using channel bars, each 75 lbs. per yard, 6 ins. wide, 2¾ ins. deep, base ¾ in. thick, flanges ⅝ in.

$$W = \frac{(33 + 5\text{-}6\ a)\ d}{L}$$

Figure 4, using T bars, each 100 lbs. per yard, 6½ ins. wide, 3½ ins. deep, flanges 1 1-17 ins. thick, plate 1¼ ins. thick.

$$W = \frac{(40 + 5\text{-}6\ a)\ d}{L}$$

TABLE OF DIMENSIONS AND FORMULÆ FOR SOLID ROLLED IRON BEAMS.

Depth of Beams, in inches.	Weight, in pounds, per yard.	Thickness of Vertical Web.	Width across Flanges.	Average Thickness of Flanges	Co-efficient C.
6	40	¼	3	·45	38
6	50	5-16	3¼	·52	46
7	60	⅜	3½	·53	65
9⅛	70	⅜	3½	·57	96
9⅛	90	½	4	·66	120
12¼	125	½	4½	·76	225
12¼	180	⅝	5⅜	·98	342
15	155	½	5	·87	350
15	200	⅝	6	·98	465

RULE—For the safe distributed load in net tons ($f = 7\frac{1}{2}$ tons), the beam resting on a support at each end: Divide the co-efficient given for the beam by the distance, in feet, between the supports.

DEFLECTION OF WROUGHT-IRON BEAMS.

To find the DEFLECTION in inches of any beam or girder, supported at each end, for the safe distributed load determined by the above formulæ.

RULE—Divide the square of the distance between the supports, estimated in feet, by fifty times the depth of the beam, estimated in inches. For any load, greater or less than that determined by the formulæ (but not more than 50 per cent. greater), the deflection will be proportionally greater or less.

For a load applied at the MIDDLE of a beam or girder supported at both ends, take one-half of the distributed load, as determined by the above formulæ, and the deflection will be 4-5 of what it would be with a uniformly distributed load, as determined by the formulæ.

For a load applied in any manner whatever on a beam supported at both ends: *First*—Find the supporting force at one end of the beam, as follows: Multiply the load applied at each point of the beam by the distance from that point to the other end of the beam. If there are loads distributed on parts of the length of the beam, assume such loads to act at their centres of gravity. Add all the products so found, and divide by the length (L) between the supports. The result so found is the supporting force at the end taken. *Second*—Proceeding from the end of the beam for which the supporting force has been found as above, towards the other end of the beam, find the first point of the beam at which the sum of the loads between that point and the end of the beam taken (including so much of any distributed loads as may be applied upon that part of the beam) becomes equal to or greater than the supporting force at the end taken. The curvature of the beam and also the strain (f) will be a maximum at that point. *Third*—Multiply each of the loads between the end of the beam taken and the point of maximum strain found as above, by the distance between that point and the point of application of the load. Assume any part of the load which may be distributed on this part of the beam to act at the centre of gravity of the part so distributed. Subtract the sum of the products so found from the product found by multiplying the supporting force at the end taken, by the distance from that end to the point of maximum strain found as above. Eight times the result so found, divided by the length (L) between the supports, will be the amount of a uniformly distributed load (W), that will be equivalent to the given load in respect to strain upon the beam, but the deflection will not necessarily be the same in the two cases.

Formulæ for Wrought-Iron Girders.

L = Length of girder (or span) in feet.
W = Weight distributed in tons.
D = Effective depth of girder in feet.
S = Strain on top and bottom flange at centre in tons.

$$S = \frac{W\,L}{8\,D}$$

If the depth $= \frac{L}{8}$ then $S = W$.

" " $= \frac{L}{10}$ " $S = 1\frac{1}{4}\,W$.

" " $= \frac{L}{12}$ " $S = 1\frac{1}{2}\,W$.

Breaking Weight of Cast-Iron Girders.

(*In tons distributed.*)

Span in feet.	Depth in inches.	Size of Bot. Flange.	Break'g Weight.	Size of Bot. Flange.	Break'g Weight.
10	10	6 × 1¼	= 31	8 × 1¼	= 41
15	15	8 × 1½	= 50	12 × 1½	= 75
20	20	10 × 1½	= 62	15 × 1½	= 94
25	25	13 × 1¾	= 94	19 × 2	= 158
30	30	15 × 2	= 125	22 × 2	= 183
35	35	17 × 2	= 141	25 × 2	= 208

Cast Iron Arches.

T = Strain at centre of arch.
t = Strain at any point, x.
L = Total load on arch.

l = Load between centre of arch and x.
V = Versed sine.
S = Span of arch.

$$T = \frac{L\,S}{8\,V}$$

$$t = \sqrt{T^2 + l^2}$$

$$V = \frac{S}{10} \text{ generally.}$$

Lattice Bridges.

N = Number of points of attachment of lattices to bottom of span.
W = Weight distributed.
S = Strain at centre of top and bottom flanges.
x = Distance of any point from abutment.
y = Strain on any lattice.
a = Distance of centre of any lattice from centre of girder.
l = Length of any lattice.
L = Length of bearing of girder or span.
D = Depth of girder (effective).

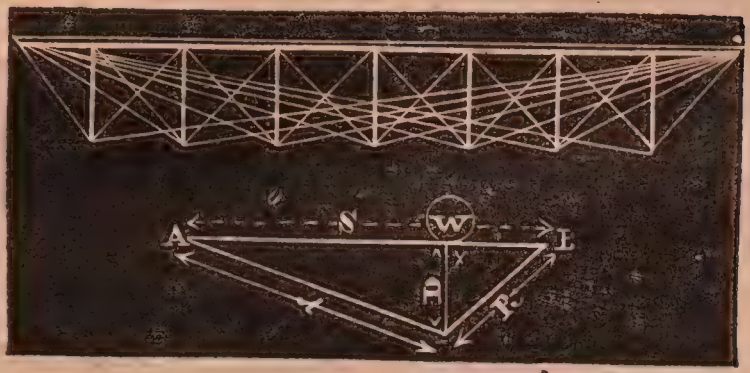
$\frac{W\,L}{8\,D}$ = S at centre; $\frac{W}{2\,D\,L}(Lx - x^2)$ = S, at any point whose distance is x from abutment.

$y = W\frac{a.l.}{D.L.}$; y is for single triangulation, and must be divided by the number of points of attachment in the base of one triangle.

If w = weight applied at centre of girder—

$\frac{w\,l}{2\,D}$ = strain on all the lattices.

American Truss Bridge.



L = Total load distributed.
N = Number of points of suspension.
$W = \frac{L}{N}$ = Load at each point of suspension.
S = Span.
A X, B X = Distance of any point of suspension from abutments A and B.
R = Length of tension rod.
r = Length of counter-tension rod.
D = Depth of truss.

Strain on tension rod $R = \frac{W.AX}{S} \times \frac{R}{D}$

Strain on counter tension $r = \frac{W.BX}{S} \times \frac{r}{D}$

Strain on perpendicular strut = W.

Strain on top at centre $= \frac{S\ L}{8\ D}$

The thick lines are in compression.
The fine lines are in tension.

D is usually $\frac{S}{7}$

Bowstring Bridges.

T = Tension of main tie and
= Thrust of arch at crown, in tons.
S = Span " " in feet.
R = Rise " " in feet.
L = Total load distributed in tons.
x = Distance of any part from centre of girder in feet.

$$T = \frac{L.S}{8\,R}$$

Thrust at any other part of arc $= \sqrt{T^2 + \left(\frac{L}{S}\right)^2 . x^2}$

Greatest tension at any perpendicular $= \frac{L}{N}$ nearly when N = No. of parts into which the arc is divided by the perpendiculars.

To Calculate Strength of Struts for Bridges, etc.

Rankine.

Of wrought iron—
D = diameter in inches.
L = length in inches.
S = sectional area of metal in inches.
W = crushing weight in tons.

When fixed at the ends, $W = 16S \div 1 \times \frac{L^2}{a\,.D^2}$

For a hollow tube, $a = 3{,}000$.
For a cross with equal arms, $a = 1{,}000$.
For an angle with equal sides, $a = 1{,}000$.
When hinged at the ends,

Take $\frac{a}{4}$

Dimensions for Howe's Truss Bridge.

Span.	Rise.	Chords.	Panel.	End Brace.	Centre Brace.	End Rod.	Counter Rod.
		No. and Size.				No. & Diam.	No. & Diam.
50	10	2—8×10	7	6×6	4×4	2—1⅛	2—1
75	12	2—8×10	9	6×6	4×4	2—1½	2—1
100	15	3—8×10	11	7×7	5×5	2—1¾	2—1
150	20	4—8×12	15	10×10	6×6	3—2	3—1
200	25	4—8×16	15	12×12	7×7	5—2	5—1

Pratt's Truss Bridge.

Span.	Rise.	Chords.	End Post.	Centre Post.	Centre Rod.	End Rod.	Counter Rod.
		No. and Size.			No. & Diam.	No. & Diam.	No. & Diam.
50	10	2—8×10	4×4	4×4	2—1⅜	2—1	1—1
75	12	2—8×10	5×5	5×5	2—1⅝	2—1	1—1
100	15	3—8×10	6×6	6×6	2—1¾	2—1	2—1
125	18	3—8×10	7×7	6×6	3—1⅞	3—1	2—1
150	21	4—8×12	8×8	6×6	3—2⅛	3—1	3—1
200	24	4—8×16	9×9	6×6	5—1⅞	5—1	3—1

Arch Brace Railroad Truss.

Span.	Rise.	Chords.	Tires.	Arch Braces.	Lattice.
		No. and Size.	No. and Size.	No. and Size.	No. & Size.
50	10	2—8 × 10	1—8 × 10	2—6 × 6	2 × 6
75	12	2—8 × 10	1—8 × 10	2—6 × 6	2 × 6
100	15	3—8 × 10	2—8 × 10	3—6 × 6	2 × 6
150	20	4—8 × 12	3—8 × 10	4—6 × 9	2 × 6
200	25	4—8 × 16	3—8 × 10	4—6 × 9	2 × 6

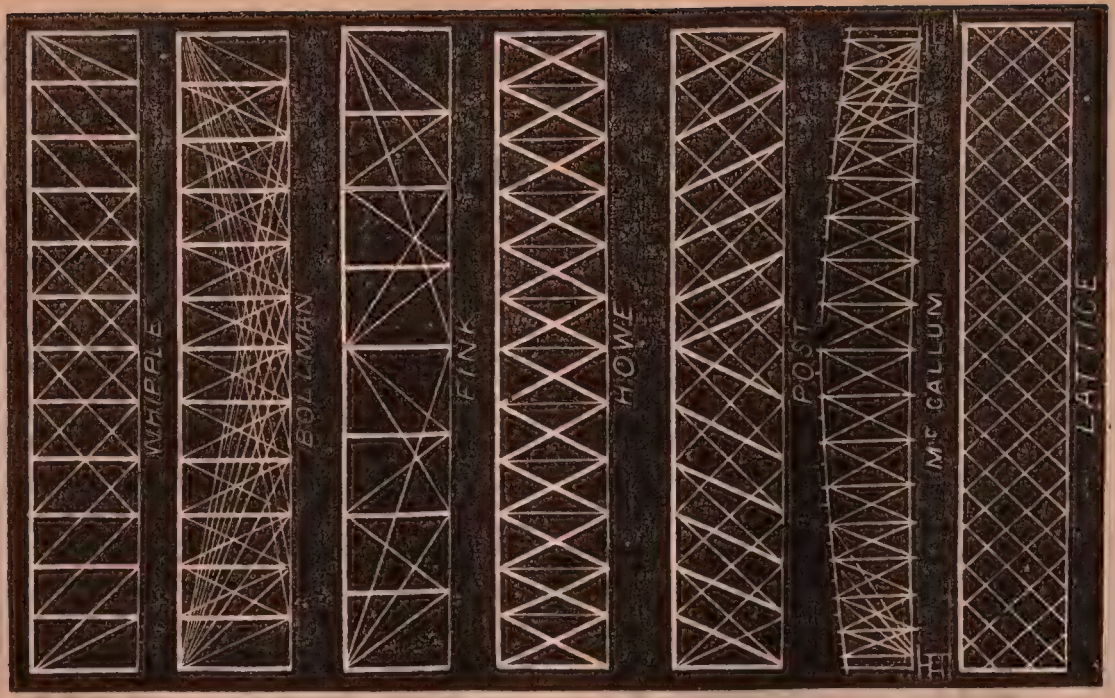


DIAGRAM OF AMERICAN BRIDGES,

By A. P. Boller, Esq., Bridge Architect, New York.

Suspension Bridges.

Z = Angle of suspension at abutments.
V = Versed sine of curve or deflection in feet.
C = Chord or span in feet.
L = Load in tons distributed, including weight of bridge.
x = Distance of any point from centre of curve.
h = Height of any point of chain above centre of chain.
S = Strain on chain in centre in tons.
s = Strain on ditto, at any point distant x from centre.

$$h = \frac{V \times x^2}{(\frac{1}{2} C)^2}$$

$$S = \frac{1}{2} L \times \text{Cotan. } Z \,*$$

$$s = S \sqrt{\left(\frac{2h}{x}\right)^2 + 1}$$

$$V = \frac{C}{13} \text{ generally.}$$

$$\text{Tan } Z \frac{4V}{C}$$

$$\text{Length of chain} = 2 \sqrt{(\tfrac{1}{2} C)^2 + \tfrac{4}{3} V^2}$$

Loads on Railway Bridges.

	Broad Gauge.	Narrow Gauge.
On bridges of 8 feet span, per foot run	3 tons.	2 tons.
" 16 " " "	2 "	1½ "
" 25 " and upwards	1½ "	1 "

Permanent Loads on Bridges, &c.

For rough calculations the weight of the bridge itself may be assumed to be (in wrought-iron bridges):

For 30 feet spans, single line	560 lbs. per foot run.
" 60 " "	672 " " "
" 100 " "	1,008 " " "
" 150 " "	1,344 " " "
" 200 " "	1,680 " " "

Dense crowds average 120 lbs. per square foot.

For flooring, 168 to 224 lbs. per square foot, exclusive of the weight of the flooring, is generally allowed.

In storehouses, from 224 to 450 lbs. per square foot.

CAST-IRON COLUMNS.

TABLE OF THE STRENGTH IN TONS OF SOLID CAST-IRON COLUMNS WITH THE ENDS FLAT AND FIXED, CALCULATED AT ABOUT ONE-TENTH OF THE BREAKING WEIGHT, ACCORDING TO HODGKINSON'S FORMULA.—*Molesworth.*

Diameter in Inches.	Length of Column in Feet								
	6	8	10	12	14	16	18	20	25
1½	.82	.50	.34	.25	.19	.15	.13	.11	.07
1¾	1.43	.87	.60	.44	.34	.27	.22	.18	.13
2	2.31	1.41	.97	.71	.55	.44	.36	.30	.20
2¼	3.52	2.16	1.48	1.08	.83	.67	.54	.46	.31
2½	5.15	3.16	2.16	1.58	1.22	.97	.80	.66	.56
2¾	7.26	4.45	3.05	2.23	1.72	1.37	1.12	.94	.64
3	9.93	6.09	4.17	3.06	2.35	1.87	1.53	1.28	.88
3½	17.29	10.60	7.26	5.32	4.10	3.26	2.67	2.23	1.53
4	27.96	17.15	11.73	8.61	6.62	5.28	4.32	3.61	2.47
4½	42.73	26.20	17.93	13.15	10.12	8.07	6.60	5.52	3.78
5	62.44	38.29	26.20	19.22	14.79	11.79	9.65	8.06	5.52
5½	88.00	53.97	36.93	27.09	20.84	16.61	13.60	11.37	7.78
6	120 4	73.82	50.51	37.05	28.51	22.72	18.60	15.55	10.64
6½	160.6	98.47	67.38	49.43	38.03	30.31	24.81	20.74	14.19
7	209.7	128.6	87.98	64.53	49.66	39.57	32.39	27.08	18.53
7½	268.8	164.8	112.8	82.73	63.66	50.73	41.53	34.72	23.76
8	339.1	207.9	142.3	104.4	80.31	64.00	52.39	43.80	29.97
8½	421.8	258 6	177.0	129.8	99.90	79.61	65.16	54.48	37.28
9	518.2	317.7	217.4	159.5	122.7	97.80	80.05	66.92	45.80
9½	629.5	386.0	264.2	193.8	149.1	118.8	97.25	81.70	55.64
10	757.2	464.3	317.7	233.1	179.3	142.9	117.0	97.79	66.92
10½	902.6	553.5	378.7	277.8	213.8	170.3	139.4	116.6	79.77
11	1067.1	654.4	447.8	328.5	252.7	201.4	164.9	137.8	94.31
11½	1252.3	767.9	525.5	385.4	296.6	236.4	193.5	161.7	110.7
12	1459.6	895.1	612.5	449.3	345.7	275.5	225.5	188.5	129.0

The correction for short columns should be applied where the length is less than 30 D.

$$\text{Strength in tons of short columns} = \frac{S\,C}{10\,S + \frac{3}{4}C}$$

S being the strength for long columns given in the above table and C = 49 times the sectional area of the metal in inches.

Hollow Columns.

The strength nearly equals the difference between that of two solid columns the diameters of which are equal to the external and internal diameters of the hollow one.

Relative Strength of Materials in Long Columns.

Cast-iron b ing assumed as	= 1,000
Wrought-iron	= 1,745
Cast-steel	= 2,518
Oak	= 109
Pine	78½

In hollow columns, the thickness of metal should not be less than $\frac{D}{12}$.

Wooden Pillars.

Approximate Rule for the Dimensions of Wooden Pillars.

W = Weight in pounds to be supported by the pillars.
L = Length of the pillar in feet.
D = Diameter of pillar in inches.

Diameter is equal to the length of the pillar in feet squared, multiplied by the square root of the weight in lbs. to be supported; multiplied by the co-efficient x. The square root of the product, equal diameter of pillar in inches.

x = .00255 for oak.
x = 00285 for ash.
x = 00312 for elm.

Ramapo Wheel and Foundry Co.

Specific Gravity.

The specific gravity of a body is the proportion it bears to the weight of another body of known density.

To Ascertain the Specific Gravity of a Fluid.

Rule—Take a body of known specific gravity, weigh it in and out of the fluid; then as the weight of the body is to the loss of weight, so is the specific gravity of the body to that of the fluid.

To Compute the Proportions of Two Ingredients in a Compound, or to Discover Adulteration in Metals.

Rule—Find the differences of each specific gravity of the ingredients and the specific gravity of the compound; then multiply the gravity of the one by the difference of the other; and as the sum of the products is to the respective products, so is the specific gravity of the body to the proportions of the ingredients.

To Find the Weights of the Ingredients, that of the Compound being Given.

Rule—As the specific gravity of the compound is to the weight of the compound, so are each of the proportions to the weight of its material.

Specific Gravity and Weights of Various Substances.

Metals.	Specific gravity.	Weight of cubic foot in lbs.	Weight of a cubic inch.
Aluminium	2.56	100	.092
Antimony	6.7	418	.242
Bismuth	9.82	615	.35
Brass, cast	8.4	525	.3
Copper	8.89	555	.32
Gold	19.25	1,203	.7
Gun Metal	8.4	525	.3
Iron, wrought	7.7	481	.28
" cast	7.18	448	.26
Lead	11.35	709	.41
Mercury	13.56	847	.49
Silver	10.47	654	.38
Steel	7.8	487	.282
Tin	7.29	455	.263
Zinc	7	437	.253

Specific Gravity and Weights of Various Substances.

Continued.

Timber.	Specific gravity.	Weight of cubic foot in lbs.
Apple	.79	48
Alder	.80	50
Ash	.80	50
Beech	.69	43
Birch	.71	44
Box	1.32	82
Cherry	.71	44
Chestnut	.61	38
Cocoa	1.04	65
Cork	.24	1.5
Cypress	.64	40
Ebony	1.33	95
Elm	.67	42
Fir	.56	35
Hacmetac	.59	37
Hickory	.90	56
Lignum Vitæ	1.33	83
Logwood	.91	56
Mahogany	1.06	66
" St. Domingo	.72	45
Maple	.75	46
Oak, live	1.120	70
" white	.78	48
Orange	.70	44
Pear	.66	41
Pine, white	.45	29
" yellow	.65	41
Poplar, white	.38	23
Plum	.78	48
Quince	.70	44
Spruce	.55	35

Specific Gravity and Weights of Various Substances.

Continued.

Description.	Specific gravity.	Weight of cubic foot in lbs.
TIMBER.		
Sassafras	.48	31
Sycamore	.60	37
Walnut	.67	41
Willow	.58	36
Yew	.8	50
MISCELLANEOUS.		
Asphaltum	.9	56
Gutta Percha	.98	61
India Rubber	.94	60
Ivory	1.8	112
Gunpowder	1.00	62
Ice	.93	58
Pitch	1.15	71
Rosin	1.10	68
Tar	1.01	62
Lard	.94	60
Sugar, dry	1.60	100
LIQUIDS.		
Alcohol	.8	50
Ether	.74	46
Oil	.90	56
Water, fresh	1.000	62.4
" sea	1.028	64.1
ARTIFICIAL SUBSTANCES.		
Brick	2.0	124
Brickwork, in mortar	1.6	100
" in cement	1.8	112 to 94

Specific Gravity and Weights of Various Substances.

Continued.

Description.	Specific gravity.	Weight of cubic foot in lbs.
ARTIFICIAL SUBSTANCES.		
Concrete, ordinary	1.9	119
" in cement	2.2	133
Cement, Portland	1.3	81
" Roman	1.	63
Glass	2.5	156
Lime, quick	.8	50
Mortar	1.7	106
Tile	1.8	112
STONES, EARTHS, ETC.		
Chalk	2.3	143
Clay	2.	125
Coal	1.3	82
Coke	.8	50
Earth, rammed	1.6	100
Flint	2.6	163
Gravel	1.9	120
Granite	2.6	164
Grindstone	2.1	131
Limestone	2.5	156
Marble	2.7	168
Sand	1.9	120
Sandstone	2.5	156
Slate	2.8	175
Shingle	1.4	90

To find the Specific Gravity of a Substance.

Weigh the substance in the air, then in water; if the substance be lighter than water, sink it by means of a heavier substance, and deduct weight of heavier substance.

W = weight of body in air.
X = weight of body in water.
G = specific gravity.

$$G = \frac{W}{W-x}$$

To find the weight of a cubic foot of any substance when the specific gravity is given, multiply specific gravity by 62.5. To find the weight of a cubic inch, multiply specific gravity by .03617.

TABLE OF TEMPERATURES WHEN BODIES CHANGE FORM.

Smelting Points.

Cast-iron	2,786	degrees.
Gold	2,016	"
Silver	1,873	"
Copper	2,160	"
Brass	1,800	"
Steel	1,873	"
Zinc	740	"
Lead	594	"
Bismuth	476	"
Tin	421	"
1 tin, 1 bismuth	283	"
3 tin, 2 lead, 5 bismuth	212	"
1 tin, 1 lead, 4 bismuth	201	"
Antimony	790	"
Sulphur	228	"
Beeswax	150	"
Tallow	92	"
Ice	32	"
1 snow, 1 salt	0	"

Boiling Points Barometer at 30 ins.

Acid, nitric	253	degrees.
" sulphuric	600	"
Alcohol	168	"
Ether	97	"
Mercury	656	"

Richmond Iron.

Oils, essential	318	degrees.
" turpentine	316	"
" linseed	640	"
Phosphorus	554	"
Sulphur	560	"
Water	212	"

Freezing Points.

Acid, nitric	— 55	degrees.
" sulphuric	— 1	"
Ether	— 47	"
Mercury	— 39	"
Milk	30	"
Olive oil	36	"
Linseed oil	— 11	"
Proof spirits	— 7	"
Spirits turpentine	16	"
Vinegar	28	"
Water	32	"

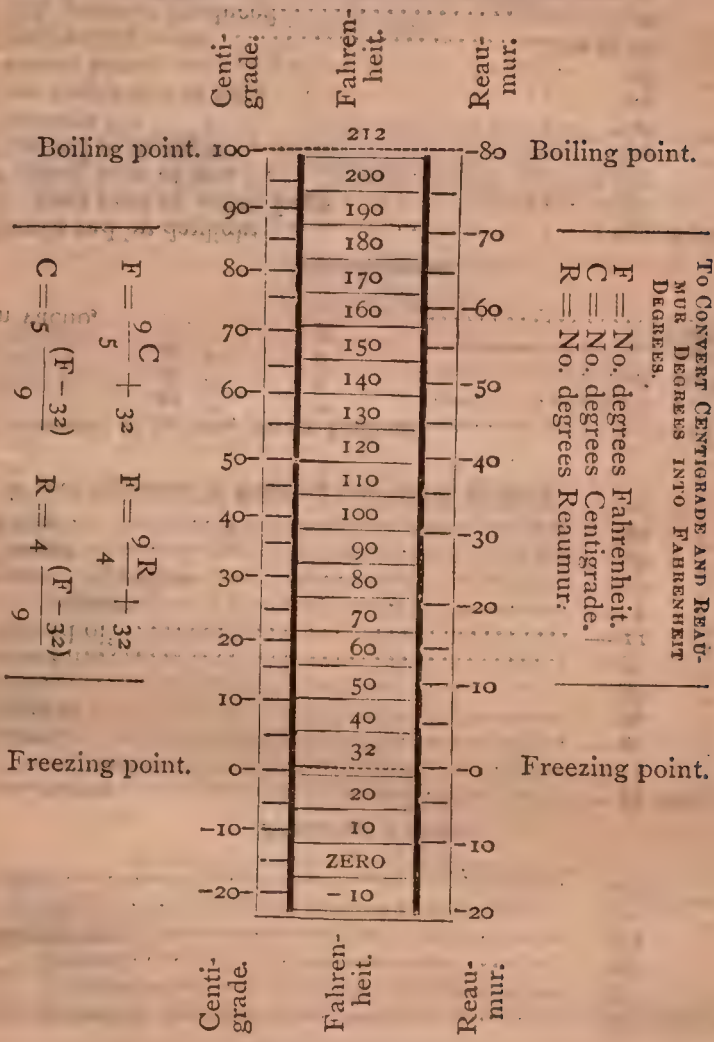
Water expands in freezing one-ninth its bulk.

Barometer at 31 ins., water boils at	213° 57
" 29 " "	210° 38
" 28 " "	208° 69
" 27 " "	206° 85
In vacuo, "	88° 00

Miscellaneous.

Metals red by daylight	1,077	degrees.
Greatest heat of smith forge	1,732	"
Welding heat of iron	1,342	"
Iron red in daylight	884	"
Common fire	790	"
Iron bright red in dark	752	"
Human blood	98	"
Comfortable room	60 to 70	"
Cold, greatest produced	— 90	"
Phosphorous burns	— 43	"

COMPARATIVE SCALE OF ENGLISH AND FRENCH THERMOMETERS.



Sixty-two Elementary Bodies, with their Symbols and Equivalents.

Body.	Symb.	Equiv.	Body.	Symb.	Equiv.
Aluminium	Al.	13 75	Nickel	Ni.	29.
Antimony	Sb.	120.	Niobium	Nr.	94.
Arsenic	As.	75.	Nitrogen	N.	14.
Barium	Ba.	68.52	Norium	No.	——
Bismuth	Bi.	213.	Osmium	Os.	97.
Boron	B.	11.	Oxygen	O.	8.
Bromine	Br.	80.	Palladium	Pd.	53.20
Cadmium	Cd.	56.	Pelopium	Pe.	——
Calcium	Ca.	20.	Phosphorus	P.	31.
Carbon	C.	6.	Platinum	Pt.	99.
Cerium	Ce.	46.	Potassium	K.	39.
Chlorine	Cl.	35.50	Rhodium	R.	52.
Chromium	Cr.	26.	Rubidium	Rb.	85.40
Cobalt	Co.	30.	Ruthenium	Ru.	52.1
Copper	Ca.	31.75	Selenium	Se.	39.50
Didymium	D.	48.	Silicon	Si.	14.
Erbium	E.	56.30	Silver	Ag.	108.
Fluorine	F.	19.	Sodium	Na.	23.
Glucinum	G.	4.66	Strontium	Sr.	43.75
Gold	Au.	197.	Sulphur	S.	16.
Hydrogen	H.	1.	Tellurium	Te.	64.
Iodine	I.	127.	Thallium	Th.	204.
Iridium	Ir.	98.	Thorium	Th.	118.
Iron	Fe.	28.	Tin	Su.	58.
Laulanium	Ln.	47.	Titanium	Ti.	25.
Lead	Pb.	103.50	Tungsten	W.	92.
Lithium	L.	7.	Uranium	U.	60.
Magnesium	Mg.	12.	Vanadium	V.	68.50
Manganese	Mn.	26.	Yttrium	Y.	30.85
Mercury	Hg.	100.	Zinc	Zn.	32.50
Molybdenum	Mo.	46.	Zirconium	Zr.	44.80

To Convert Chemical Formulæ into a Mathematical Expression.

Rule—Multiply together the equivalent and exponent of each substance, and the product will give the proportion in the compound, by weight. Divide 1,000 by the sum of their products, and multiply this quotient by each of these products, and the products will give the respective proportion of each part, by weight, in 1,000.

IRON.

Iron is found usually in ores, in the state of an oxide, combined with earthy or stony matters, and sometimes with *sulphur*, *antimony*, *arsenic*, *magnesia*, *manganese*, *phosphorus*, and *copper*.

Iron ores are classed as *Magnetic*, *Specular*, *Micaceous*, *Red Hematite*, or *Brown Hematite*, according to their different combinations. The foreign compounds iron contains vary its quality.

Pure iron has specific gravity of 7.3 to 7.8; hardness, 4.5; chemical equivalent, 28. It is most tenacious of metals; the hardest of all those which are malleable; has a slight smell when rubbed; is astringent to the taste; in moist atmospheres oxidizes and becomes covered with a coating called *rust;* it is attracted by the magnet; becomes magnetic by induction; loses its polarity when removed from the magnet.

When combined with 2 to 5 per cent. *carbon*, is fusible *cast iron;* with less than ½ per cent., is *malleable iron;* ½ per cent., very *soft steel;* 1 per cent., cast steel. 1.4 to 1 5 per cent. of carbon in iron denotes maximum of strength with hardness; 1.75 per cent. carbon, steel weldable in a slight degree; 2 per cent., fusible cast iron.

Sulphur renders iron fusible, difficult to weld when hot; called *red-short.*

Phosphorus renders it *cold-short*, or brittle when cold.

Silicon tends to make iron brittle, crystalline structure, and very weak, and to diminish yield of iron in puddling furnace.

Antimony, *arsenic*, and *copper*, same effect as sulphur—the last in a greater degree.

Manganese, to harden and improve quality of iron or steel.

Cast Iron.

Cast iron is known as either charcoal, coke, bituminous, anthracite, hot-blast, and cold-blast, from the nature of the fuel

used and method of smelting. Charcoal irons are the strongest of all cast irons. They are known as either *foundry irons*, used for castings, or *forge irons*, only used for making wrought iron. Cast irons are classed as either gray, mottled, or white irons, in proportion to the amount of carbon contained, whether in combined state of mechanical diffusion as graphite carbon, or as chemically-combined carbon. White iron contains 5½ per cent. combined carbon; gray iron, 3 to 4 per cent. graphite carbon. Grades are subdivided according to their relative hardness (proportion of carbon), into No. 1; Soft No. 2; Hard No. 2; No. 3; No. 4, *Bright;* No. 5, Mottled; No. 6, White.

No. 1 is the softest iron, not much strength, used to mix with other harder irons. No. 2 is harder and closer grained, stronger than No. 1, gray color, lustre good; No. 3 harder than No. 2, gray, inclining to white, used for car wheels, and mixing with other irons. No. 4 is *bright* iron; No. 5, *mottled;* No. 6, *white*—never used by itself.

Remelting increases the density—hence purity and tenacity of cast iron; gray iron most by decarbonizing, which is aided by allowing the metal to be exposed to the action of heat; with white irons improvement is not so marked. After the third or fourth fusions cast iron is not fit for small castings, is subject to unequal expansion and contraction, and, if large, rarely solid. Tenacity of iron is in the ratio of the 10th power of its specific gravity. Tenacity and a low specific gravity or density are incompatible.

Gray Iron is not as hard, and less brittle, than white iron; is slightly malleable and flexible; is not sonorous; can be easily worked by tools; has a brilliant fracture of a gray or bluish gray hue; color is lighter as the grains are closer, giving increased hardness contains 3 to 4 per cent. graphitic carbon; melts at less temperature than white iron; remains longer fluid, is red when melted; redness increases as temperature diminishes; gives a sharp casting contracts less than white iron; has fewer cavities, and gives a smooth and *convex* surface to the casting. A medium-sized grain, bright gray color, sharp fracture to the touch, and close texture, are evidences of good quality of iron. A very

large or very small grain, of a dull, earthy hue, loose texture, crystals of varied form, indicate poor iron. Specific gravity is 7.2. Gravity and tenacity *decrease* by annealing.

WHITE IRON contains chemically-diffused carbon up to 5⅛ per cent.; is very brittle and sonorous; resists file and chisel; is susceptible of high polish; has *concave* surface to its castings; fracture silvery; fine-grained, compact, sometimes lamellar; when melted is white; throws off sparks in profusion; qualities the reverse of gray iron. Mean specific gravity, 7.5. Tenacity is *increased* and specific gravity decreased by annealing.

MOTTLED IRON is a mixture of white and gray irons; has a speckled appearance; flows well; few sparks; contracts but little in casting; castings have a plane surface, with edges rounded; is used for CAR WHEELS and ORDNANCE.

N. B.—It has been generally believed that the DARK GRAY cast iron, No. 1 or No. 2, contains more carbon than WHITE IRON does, and that the superior quality of the gray iron, in tenacity and softness, was due to excess of carbon. On the contrary, WHITE IRON contains say 5⅓ per cent. of carbon, or as much as the iron in a liquid state can absorb, and is thoroughly combined with the metal, as in steel; while gray iron contains from 3 to 4 per cent., existing in a state of graphite or plumbago, dispersed in particles. The softness and tenacity of the iron is owing to the altered combination of the carbon.

When dark gray cast iron is melted and suddenly cooled, it gives a silvery white metal, hard and brittle. In white cast iron, cooled very slowly, the condition of carbon changes, and a dark gray iron is obtained, proving that graphite or plumbago, which requires a high temperature for its formation, cannot be produced except by a slow process of cooling, which allows the carbon to agglomerate itself in the iron in the state of graphite; while under rapid cooling, the carbon remains dissolved in the mass, and produces a white metal.

Hence, we may see how each successive fusion of dark gray iron hardens and whitens it, though in contact with fuel, by completing that chemical dissolution of the carbon on which the white state depends.

Magnetic irons undergo less alteration in fusion than hematite irons. In an air furnace Hematite No. 1 has been changed to *white* in a single melting.

GRAPHITE or PLUMBAGO is a mineral substance of a lead or iron-gray color, metallic lustre, soft to the touch; specific gravity, 2.08 to 2.45; consists of carbon in a peculiar state of aggregation, with an extremely minute, and apparently accidental, impregnation of iron.

Notes on Cast Iron.

Green-sand iron castings are 6 per cent. stronger than dry-sand, and 30 per cent. stronger than chilled; but when castings are chilled and annealed, as in car wheels, a gain of 115 per cent. is attained over green-sand castings.

A mixture of 30 per cent. of wrought iron with cast iron, carefully fused in a crucible, increases strength of cast iron one third.

Chilling the under side of cast iron materially increases its strength.

Chilled bars of cast iron deflect more readily than unchilled.

Girders cast with face up are stronger than when cast on side, as 1 to .96; also strongest when cast with bottom flange up.

The mean tensile strength of cast iron is from 16,000 to 20,000 lbs. The value of it, when subjected to a tensile strain, may be safely estimated at from ¼ to ½ of this, or of its breaking strain.

Extension of cast iron, at its limit of elasticity, is estimated at the 1200th part of its length. The ultimate extension is the 500th part of its length.

Cast iron, at 2.5 tons per square inch, will extend same as wrought iron at 5.6 tons.

Mean strength of American cast iron, determined by Major Wade for the Ordnance Corps, is 31,829 lbs. per sq. in. of section. Major Rodman—Richmond iron, 37,744 lbs.; mean of English cast iron (R. R. Coms., 1849), 19,484 lbs.; English gun metal (Woolwich Arsenal, 1858), 23,257 lbs.

The resistance to compression is greater than to extension. A cast iron beam will bend with one-third of its breaking weight, if the load is laid on gradually—one-sixth, if laid on at once, will produce same effect, hence should be capable of bearing six times the greatest weight which can be laid on it.

In cast iron the 1-20 to 1-30 of the breaking weight will give a visible set.

Cast and wrought iron beams, having similar resistances, have weights as 2.44 to 1.

Girders of cast iron, up to 40 feet, cost less than wrought iron; best form of section is the Hodgkinson I; when subject to a fixed load, flange should be as 1 to 6; when to concussion, as 1 to 4.

Cast iron will expand or contract for each degree of heat 0.000006173, or the 162000th of its length; shrinks in cooling from 0.0104 to 0.0118 of its length: will contract or expand in the extreme ranges of temperature of this country, the 1157th part of its length, or with a force equal to 4¾ tons per square inch.

To Fill Holes in Cast Iron—Use a cement of sulphur in powder, 1 part; sal ammoniac, 2 parts; powdered cast-iron turnings, 80 parts. Mix into a thick paste. The ingredients should be kept separate, and not mixed until required for use.

To Prevent Iron from Rusting—Warm it, rub with white wax; put again before fire, until wax has pervaded entire surface.

Varnish for Iron and Steel.—Clear grains of mastic, 10 parts; camphor, 5 parts; sandarach, 15 parts; elemi, 5 parts. Dissolve in alcohol. Apply without heat. Will retain its transparency and metallic lustre of the metal.

Wrought Iron.

Wrought iron is made from *pig iron*, either in a bloomery fire or in a puddling furnace, by melting and keeping it exposed to a great heat and action of the flame, and constantly stirring the mass, until the carbon is removed. The softest and finest irons contain a small per cent. of carbon—up to ½ per cent. when it is steely iron or can be hardened.

Refined iron is pig iron further decarbonized by remelting and continued action of heat; is run into thin chilled plates, and worked in the puddling furnace. Other things being equal, the best iron is that which has been most wrought.

All iron contains more or less carbon—the hardest the most; proportion varies from 0.293 to 0.66 per cent.; specific gravity, 7.788.

Mean strength of American wrought iron is 55,900 lbs.; English, 53,900. Ultimate extension of wrought iron is 600th part of its length.

Breaking strain is from ¼ to ⅓ mean strength.

Resistance to flexure, acting evenly over the surface, equals ½ the tensile strength.

Bars of wrought iron will expand or contract 151200ths of their length for each degree of heat. With range of temperature of this country (− 20 to + 120°) = 140°, will expand or contract 1080th of its length, equal to a force 20,740 lbs., or 9¼ tons per square inch of section. Tensile strength increases in from 1 to 6 reheatings and rollings, from 43,904 lbs. to 61,824 lbs.; in from 6 to 12, is reduced again to 43,904.

In iron the tensile strength for 60° Fahr. is 1; 114°, 1.14; 212°, 1.2; 250°, 1.32; 270°, 1.35; 325°, 1.41; 435°, 1.4.

To Test Quality of Iron.—If fracture gives long silky, fibres of leaden-gray hue, fibres cohering and twisting together before breaking, may be considered a *tough soft iron*. A medium, even grain, mixed with fibres, a good sign. A short, blackish fibre, indicates badly refined iron. A very fine grain denotes a *hard steely iron*, apt to be cold-short, hard to work with a file. Coarse grain, with brilliant crystallized fracture, yellow or brown spots, denote a *brittle iron*, cold-short, working easily

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Richmond Iron.

when heated; welds easily. Cracks on the edge of bars, sign of hot-short iron.

Good iron is readily heated, soft under the hammer, throws out but few sparks.

NOTE ON FORGINGS.—Iron, while heating, if exposed to air, will *oxidize;* when at white heat, if in contact with coal, will *carbonize*, or become steely.

Iron should be heated as rapidly as possible.

TO RESTORE BURNT IRON—Give a smart heat, protected from the air; if injured by *cold hammering*, anneal slowly and moderately; if *hard* or *steely*, give one or more smart heats, to extract the carbon.

STEEL.

Steel is a compound of iron and carbon, varying in proportion of 0.5 per cent. to 5 per cent. of carbon. Specific gravity, 7.8; tensile strength, 120,000 lbs. per square inch. Ordinary steel is carbon steel, but steely compounds of iron have been produced, which have the same general properties as ordinary steel, the carbon of which is replaced by other chemical elements. Thus tungsten steel, where tungsten is combined with the iron; manganese steel; chromium steel; titanium steel, where the steel is invariably a compound of iron with other metals.

Other varieties contain non-metallic bodies as the steel-generating material; carbon is one of these elements; also silicon, the basis of flint, a near chemical relative to carbon, giving silicon steel; also boron, the basis of borax, another near relative to carbon and silicon, gives boron steel, having cutting qualities, which enables tools made of it to do thirteen times the work of ordinary carbon steel tools. There are also phosphorus steel and sulphur steel. Steel may be produced by two processes, opposed to each other: First—By working pig iron, which contains from 4 to 5 per cent. carbon, in a furnace, until such carbon is reduced to 1 per cent.—quantity required for producing steel; or, Secondly—By heating bars of wrought iron in contact with charcoal, until they have absorbed requisite quantity of carbon; steel thus made is known as cemented or blistered steel.

Steel is known as either: 1st—*Natural Steel:* made from pig

iron direct, smelted from spathose iron ores, containing 4 to 5 per cent. manganese, which produce a highly crystalline metal, called spiegle-eisen, on account of the large crystals the metal presents; 2d—*Cemented Steel;* 3d—*Cast Steel.*

Blistered steel is same as cemented steel. *Tilted steel* is blistered steel, heated and worked under a tilt hammer. *Shear steel* is blistered steel, put into a fagot, welded in a reverbatory furnace, and hammered or rolled into bars.

Cast steel is made by melting, in covered crucibles, pieces of blistered steel; the metal then is poured into iron moulds. The *ingot* is reduced to a bar by hammering or rolling. It is the best kind of steel; has a fine even grain; silvery, homogeneous fracture; very brittle; difficult to weld without a flux.

Properties of steel are: after tempering, not easily broken; welds readily; does not crack or split; bears a very high heat; can be hardened after repeated workings.

Is magnetic, and, as distinguished from iron, when once magnetized, does not lose its polarity at ordinary temperatures.

Bessemer Process of Making Iron or Steel.

Process consists in decarbonizing cast iron by means of forcing atmospheric air through a mass of molten metal, the oxygen of the atmosphere combining with the carbon contained in the iron, produces carbonic acid gas, at the same time evolving a powerful heat. The metal absorbs the intense heat diffused through the mass, and in fifteen or twenty minutes after the application of the air, the mechanically mixed carbon or graphite is entirely consumed. The high temperature causes the chemically combined carbon to separate from the metal, as indicated by flame and immense shower of sparks; the metal boils up, giving forth a frothy slag, which is thrown out in foam-like masses. The rapid union of the oxygen and carbon add still further to the temperature of the metal, while the dimished amount of carbon allows a part of the oxygen to combine with the iron, which undergoes combustion, and is converted into an oxide; at the excessive temperature the metal has acquired, the

oxide, as soon as it is formed, undergoes fusion, and forms a violent solvent of the earthy bases associated with the iron; the ebullition washes and cleanses the metal from the silica and earthy bases, while the sulphur and other volatile matter are combined with the oxygen, and pass off as gases. By adding different proportions of a highly carbonized metal to the decarbonized metal, steel of varying density can be made.

To Test Iron by Magnetism.

To detect a false weld in a forging or honey-comb in an iron or steel casting, until the invention or discovery of Mr. S. M. Saxby, R. N., has been often an impossibility.

It has long been known that iron, in a bar or soft mass, placed in the position of the dipping needle, becomes sensibly magnetic, the lower extremity being the north pole, and the upper a south, in our latitude. In the Southern Hemisphere poles are reversed. When a small compass needle is slowly passed in front of a bar of very good iron, placed in an east and west direction, the needle will not be disturbed from its proper direction, which is, of course, at right angles to this, or north and south.

But this is only true of homogeneous bars of best quality—bars without any mechanical solutions of continuity. With internal flaws, the bar is no longer regularly magnetic. Any mechanical solution of continuity is accompanied with a polar solution of continuity, and the given bar or mass with flaws—whether permanently magnetized, or temporarily so by the inductive action of the earth—is no longer one regular magnet, but a series of magnets, with the different magnetisms separated from each other. The delicate-poised magnet moved in a line parallel with the axis of a bar placed *east* and *west*, as long as the iron is sound will remain *north* and *south*, but on recurrence of a flaw will deviate more or less until entirely reversed when placed over the imperfect spot.

Mr. Saxby's method can determine the presence and absence of small or large solutions of continuity; detect false welds, smaller flaws caused by bad workmanship or wear, and crystallization.

Ramapo Wheel and Foundry Co.

PIERSONS & CO.,

(*Established in* 1790,)

IMPORTERS AND DEALERS IN

IRON AND STEEL,

24 BROADWAY, AND 77 & 79 NEW ST., N. Y.

ALL SIZES

LOCOMOTIVE IRON

KEPT IN STOCK.

BARS, RODS, HOOPS, SCROLLS, BANDS, OVALS, HALF OVALS, HALF ROUNDS, ANGLE IRONS, SHEET IRON, SPRING, CAST, TIRE, AND TOE-CORK STEEL.

METALS.—Properties of Metals.

METALS.	Weight of a cubic in. in lbs.	Specific Gravity.	Weight of a cubic ft. in lbs.	Tenacity in lbs. per sq. inch.	Crushing force in lbs. per sq. inch.	Melting Point. Fahr.	Expansion betw'n 32 and 212 degrees.	Conducting Power.	Specific Heat.
Aluminium	.092	2.56	160	..	..	*1800°	..	..	..
Antimony, cast...	.242	6.7	418	1,066	..	810°	.0011	..	.0507
Bismuth.....	.35	9.82	615	3,250	..	497°	.0014	..	.0288
Brass, cast.....	.3	8.4	525	17,978	10,300	1800°	.002	..	..
" wire	..	8.5	531	49,000	..	..	..	..	..
Copper, cast.....	.32	8.89	555	19,072	11,700	1996°	.0017	..	.0949
" sheet....	..	8.95	559	33,000	..	..	..	898	..
" wire	..	9.	562	61,000	..	..	..	..	..
Gold.....	.7	19.25	1,203	20,400	..	2016°	.0016	1,000	.0298
Gun metal.....	.3	8.4	525	36,000	..	..	..	..	..
Iron, wrought bar.	.28	7.7	481	60,000	38,000	..	.0012	347	.1100
" Swedish....	..	7.6	475	70,000	..	..	..	..	..
" wire	..	..	..	85,000	..	..	..	..	..
" cast.....	.26	7.18	448	19,000	92,000	2786°	.0011	.	..
Lead, cast	.41	11.35	709	1,824	7,000	612°	.0028	180	.0293
" sheet.....	..	..	..	3,328	..	..	..	..	..
Mercury.....	.49	13.56	847	..	..	—39°	.016	..	.0330
Silver	.38	10.47	654	41,000	..	1873°	.0019	973	.0557
Steel.....	.282	7.8	487	120,000	..	..	.0011	..	..
" puddled....	..	7.78	485	80,000	..	..	..	..	..
Tin	.263	7 29	455	5,000	15,000	442°	.0021	304	.0514
Zinc.....	.253	7.	437	8,000	..	773°	.0029	363	.0927

* Approximate; no well-authenticated experiments on Aluminium.

Ramapo Wheel and Foundry Co.

WEIGHTS OF METALS, Etc.

Birmingham Wire Gauge, Compared with Inches.

B. W. G. = ins.		B. W. G. = ins.		B. W. G. = ins.		B. W. G. = ins.	
No. 1 =	.31	No. 10 =	.137	No. 19 =	.042	No. 28 =	.014
2	.28	11	.125	20	.035	29	.013
3	.26	12	.109	21	.032	30	.012
4	.24	13	.095	22	.028	31	.01
5	.22	14	.083	23	.025	32	.009
6	.2	15	.072	24	.022	33	.008
7	.187	16	.065	25	.02	34	.007
8	.166	17	.056	26	.018	35	.005
9	.158	18	.049	27	.016	36	.004

Weight of a Square Foot of Sheet Metals in Lbs.

Thickness Birmingham Wire Gauge.

Thickness. B. W. G	Iron.	Copper.	Brass.	Thickness. B. W. G.	Iron.	Copper.	Brass.
30	.5	.58	.55	15	2.82	3.27	3.10
29	.56	.64	.61	14	3.12	3.60	3.43
28	.64	.74	.70	13	3.75	4.34	4.12
27	.72	.83	.79	12	4.38	5.08	4.81
26	.80	.92	.88	11	5.00	5 80	5.50
25	.90	1.04	.99	10	5.62	6.50	6.18
24	1.00	1.16	1.10	9	6.24	7.20	6.86
23	1.12	1.30	1.23	8	6.86	7.90	7.54
22	1.25	1.45	1.37	7	7.50	8.70	8.25
21	1.40	1.62	1.54	6	8.12	9.40	8.93
20	1.54	1.78	1.69	5	8.74	10.10	9.61
19	1.70	1.97	1.87	4	10.00	11.60	11.00
18	1.86	2.15	2.04	3	11.00	12.75	12.10
17	2.18	2.52	2.40	2	12.00	13.90	13.10
16	2.50	2.90	2.75	1	12.50	14.50	13.75

Rule for finding the Weight of Castings or Forgings by the Weight of their Patterns.

Weight of pattern in white pine.....	× 16	= cast-iron.
" " "	× 17.1	= wrought-iron.
" " "	× 17.3	= steel.
" " "	× 18	= copper.
" " "	× 25	= lead.

Shrinkage of Castings.

In locomotive cylinders.....	= 1-16 inch in a foot.
In pipes.....	= 1-8 "
Girders, beams, etc.....	= 1-8 in 15 inches.
Engine beams, connecting rods.....	= 1-8 in 16 "
In large cylinders, say 70-inch diameter, 10-feet stroke, the contraction of diameter.....	= 3-8 at top.
Ditto.....	= 1-2 at bottom.
Ditto, in length.....	= 1-8 in 16 inches.
In thin brass.....	= 1-8 in 9 "
In thick brass.....	= 1-8 in 10 "
In zinc.....	= 5-16 in a foot.
In lead.....	= 5-16 "
In copper.....	= 3-16 "
Bismuth.....	= 5-32 "
Tin.....	= 1-4 "

Copying Ink.

Add one ounce of moist sugar to every pint of common ink.

Indelible Ink for Marking Linen.

Nitrate of silver, 1 part; water, 6 parts; gum, 1 part. Dissolve, if too thick, with warm soft water.

Alloys.

Alloys.	Tin.	Copper.	Zinc.	Antimony.	Lead.	Bismuth.
Brass, engine bearings	13	112	¼	..	..	..
Tough brass, engine work	15	100	15	..	..	..
" for heavy bearings.	25	160	5	..	..	..
Yellow brass, for turning	..	2	1	..	..	..
Flanges to stand brazing	..	32	1	..	1	..
Bell metal	5	16	..	..	..	..
Babbitt's metal	10	1	..	1	..	..
Brass, for locomotive bearings.	7	64	1	..	..	..
" for straps and glands	16	130	1	..	..	..
Muntz's sheathing	..	60	40	..	..	..
Metal to expand in cooling	..	..	..	2	9	1
Pewter	100	..	..	17	..	..
Spelter	..	1	1	..	..	..
Statuary bronze	2	90	5	..	2	..
Type metal, from	..	..	..	1	3	..
" to	..	..	..	1	7	..
Solders.						
For lead	1	..	..	..	1½	..
" tin	1	..	..	..	2	..
" pewter	2	..	..	..	1	..
" brazing (hardest)	..	3	1	..	..	..
" " (hard)	..	1	1	..	..	..
" " (soft)	1	4	3	..	..	..
" " " or	2	..	..	1	..	..

Fluxes for Soldering or Welding.

Iron or steel	Borax or sal ammoniac.
Tinned iron	Resin or chloride of zinc.
Copper and brass	Sal ammoniac or chloride of zinc.

Zinc.....Chloride of zinc.
Lead.....Tallow or resin.
Lead and tin pipes.....Resin and sweet oil.

Weight of a Superficial Foot of Plates.

Different Metals, in lbs.

Thick. inches.	Iron.	Brass.	Copper.	Lead.	Zinc.	Thickness.
1-16	2.5	2.7	2.9	3.7	2.3	.0625 in. = 16 B W G
1-8	5.	5.5	5.8	7.4	4.7	.125 " = 11 "
3-16	7.5	8.2	8.7	11.1	7.0	.1875 " = 7 "
1-4	10.	11.0	11.6	14.8	9.4	.25 " = 4 "
5-16	12.5	13.7	14.5	18.5	11.7	.3125 " = 1 "
3-8	15.	16.4	17.2	22.2	14.0	.375
7-16	17.5	19.2	20.0	25.9	16.4	.4375
1-2	20.0	21.9	22.9	29.5	18.7	.5
9-16	22.5	24.6	25.7	33.2	21.1	.5625
5-8	25.	27.4	28.6	36.9	23.4	.625
11-16	27.5	30.1	31.4	40.6	25.7	.6875
3-4	30.	32.9	34.3	44.3	28.1	.75
13-16	32.5	35.6	37.2	48.0	30.4	.8125
7-8	35.	38.3	40.0	51.7	32.8	.875
15-16	37.5	41.2	42.9	55.4	35.1	.9375
1	40.	43.9	45.8	59.1	37.5	1.000

Blue Ink.

Sulphate of indigo, dilute with water, until it produces color required.

Ink for Writing on Steel, Tin Plate, or Sheet Zinc.

Mix one ounce of powdered sulphate of copper, and half ounce powdered sal ammoniac, with two ounces of diluted acetic acid, adding lamp black or vermillion.

Ramapo Wheel and Foundry Co.

Weight of Copper and Lead Pipes.

In lbs. per foot lineal.

Weight of Copper Pipes in lbs. per foot lineal.					Weight of Lead Pipes in lbs. per foot lineal.			
Bore inch.	Thickness in parts of inch.				Bore inch.	Common lbs.	Middling. lbs.	Strong. lbs.
	1-16	1-8	3-16	1-4				
½	.42	.94	1.60	2.27	½	1.07	—	—
¾	.62	1.33	2.17	3.02	¾	1.6	1.8	2.
1	.79	1.69	2.66	3.77	1	2.0	2.6	2.8
1½	1.15	2.44	3.85	5.30	1¼	3.0	3.7	4.4
2	1.55	3.21	5.00	6.80	1½	4.0	4.7	5.6
2½	1.94	3.97	6.13	8.31	2	5.0	6.0	7.0
3	2.3	4.73	7.24	9.84	2½	7.0	8.6	10.0

Hoop Iron.

Dimensions and Weight in Lbs. per Foot Run.

Breadth.....	⅝	¾	⅞	1 in.	1⅛	1¼
B. W. Gauge.....	21	20	19	18	17	16
Weight per lineal foot...	.0666	.0875	.1216	.1636	.21	.27

Breadth.....	1⅜	1½	1¾	2 in.	2¼	2½
B. W. Gauge.....	15	15	14	13	13	12
Weight per lineal foot...	.33	.36	.484	.634	.714	.91

Sheet Iron.

Weight of a Superficial Foot.

B. W. Gauge.	Dec. of an inch.	Weight in lbs.	B. W. Gauge.	Dec. of an inch.	Weight in lbs.
00000 (½)	.500	20.208	16 (1-16)	.063	2.546
0000	.450	18.187	17	.055	2.223
000	.437	17.662	18	.048	1.940
00 (⅝)	.375	15.156	19	.042	1.697
0	.340	13.742	20	.035	1.415
1 (5-16)	.312	12.610	21	.033	1.334
2	.284	11.477	22	.029	1.172
3	.261	10.549	23	.028	1.132
3—4 (¼)	.250	10.104	24	.025	1.014
4	.239	9.660	25	.021	.849
5	.217	8.770	26	.020	.808
6	.208	8.407	27	.018	.727
7 (3-16)	.187	7.558	28	.015	.606
8	.166	6.709	29	.013	.525
9	.158	6.386	30	.012	.485
10	.137	5.537	31	.010	.404
11	.125	5.052	32	.009	.364
12	.109	4.405	33	.008	.323
13	.094	3.799	34	.007	.283
14	.080	3.233	35	.005	.202
15	.072	2.910	36	.004	.162

For Steel Plates, multiply tabular number by 1.014.

Zinc Sheets.

Thickness and Weight per Square Foot.

Inch.	Inch.	Inch.
.0311 = 10 oz.	.0534 = 14 oz.	.0686 = 18 oz.
.0457 = 12 oz.	.0611 = 16 oz.	.0761 = 20 oz.

Dimensions and Weights of Seamless Brass and Copper Tubes.

(*American Tube Works.*)

External Diam.	Extreme Length.	Weight per foot.	B. Wire Gauge.	External Diam.	Extreme Length.	Weight per foot.	B. Wire Gauge.
Ins.	Feet.	Lbs.	No.	Ins.	Feet.	Lbs.	No.
5/8	8	.375	18	2	15	2.05	12 & 14
3/4	11	.5	17	2 1/8	12	2.5	" "
7/8	7	.625	17	2 1/4	13	2.375	" "
1	8	.75	12 & 14	2 3/8	12	2.5	" "
1 1/4	13	1.25	" "	2 1/2	12	2.66	" "
1 1/2	13	1.5	" "	2 5/8	12	3.	" "
1 5/8	12	1.625	" "	3	13	3.33	" "
1 3/4	13	1.75	" "	3 1/4	10	3.875	" "
1 13-16	12	1.813	" "	3 1/2	9	4 25	12
1 7/8	12	1.875	" "	4	7 1/2	5.	12

Table showing the Thickness and Weight of Galvanized Sheet Iron—Sheets 2 feet by 6 to 9 feet.

Wire Gauge.	Weight per sq. foot.	Wire Gauge.	Weight per sq. foot.	Wire Gauge.	Weight per sq. foot.	Wire Gauge.	Weight per sq. foot.
No.	Oz.	No.	Oz.	No.	Oz.	No.	Oz.
30	10	26	15	22	21	18	37
29	11	25	16	21	24	17	43
28	12	24	17	20	28	16	48
27	14	23	19	19	33	14	60

Weight of a Lineal Foot of Flat Bar Iron in Pounds.

Breadth in inches.	Thickness in Fractions of Inches.						
	¼	⅜	½	⅝	¾	⅞	1
1	.83	1.25	1.67	2.08	2.50	2.92	3.34
1⅛	.93	1.40	1.87	2.34	2.81	3.28	3.75
1¼	1.04	1.56	2.08	2.60	3.13	3.65	4.17
1⅜	1.14	1.72	2.29	2.87	3.44	4.01	4.59
1½	1.25	1.87	2.50	3.13	3.75	4.38	5.00
1⅝	1.35	2.03	2.71	3.39	4.07	4.70	5.43
1¾	1.46	2.19	2.92	3.65	4.38	5.11	5.84
1⅞	1.56	2.34	3.13	3.91	4.69	5.47	6.26
2	1.67	2.50	3.34	4.17	5.01	5.86	6.68
2⅛	1.77	2.66	3.55	4.43	5.32	6.21	7.10
2¼	1.87	2.81	3.76	4.69	5.63	6.57	7.52
2⅜	1.98	2.97	3.96	4.95	5.95	6.94	7.93
2½	2.08	3.13	4.17	5.21	6.26	7.30	8.35
2⅝	2.19	3.28	4.38	5.47	6.57	7.67	8.77
2¾	2.29	3.44	4.59	5.74	6.88	8.03	9.18
2⅞	2.40	3.60	4.80	6.00	7.20	8.40	9.60
3	2.50	3.75	5.01	6.26	7.51	8.76	10.02
3¼	2.71	4.07	5.43	6.78	8.14	9.49	10.86
3½	2.92	4.38	5.84	7.30	8.76	10.23	11.69
3¾	3.13	4.68	6.26	7.82	9.39	10 95	12.52
4	3.34	5.00	6.68	8.35	10.02	11 09	13.36
4¼	3.54	5.32	7.09	8.87	10.64	12.42	14.19
4½	3.75	5.63	7.51	9.39	11.27	13.15	15.03
4¾	3.96	5.94	7.93	9.91	11.89	13.88	15.86
5	4.17	6.26	8.35	10.44	12.52	14.61	16.70
5¼	4.38	6.57	8.76	10.96	13.14	15.34	17.53
5½	4.59	6.88	9.18	11.48	13.77	16.07	18.37
5¾	4.80	7.20	9.60	12.00	14.40	16.80	19.20
6	5.01	7.51	10.02	12.53	15.03	17.53	20.05

Weight of a Lineal Foot of Round and Square Bar Iron, in Lbs.

Diameter or Side.	Square Bars.	Round Bars.	Breadth or Diameter in inches.	Square Bars.	Round Bars.	Breadth or Diameter in inches.	Square Bars.	Round Bars.
1-4	.209	.164	1	3.34	2.62	2⅞	27.61	21 68
5-16	.326	.256	1⅛	4.22	3.32	3	30.07	23.60
3-8	.470	.369	1¼	5.25	4.09	3¼	35.28	27.70
7-16	.640	.502	1⅜	6.35	4.96	3½	40.91	32.13
1-2	.835	.656	1½	7.51	5.90	3¾	46.97	36.89
9-16	1.057	.831	1⅝	8.82	6.92	4	53.44	41.97
5-8	1.305	1.025	1¾	10.29	8.03	4¼	60.32	47.38
11-16	1.579	1.241	1⅞	11.74	9.22	4½	67 63	53.12
3-4	1.879	1.476	2	13.36	10.49	4¾	75.35	59.18
13-16	2.205	1.732	2⅛	15.08	11.84	5	83.51	65.58
7-8	2.556	2.011	2¼	16.91	13 27	5¼	92.46	72 30
15-16	2.936	2.306	2⅜	18.84	14.79	5½	101.03	79 35
			2½	20.87	16 39	5¾	114.43	86.73
			2⅝	23.11	18.07	6	120.24	94.43
			2¾	25.26	19.84			

To convert into weight of other metals, multiply tabular No. for cast-iron by .93, for steel × 1 01, for copper × 1.15, for brass × 1.09, for lead × 1.48, for zinc × .92.

Weight of Boiler Iron.

1-8	inch iron weighs	.....	5	pounds per	square	foot.
3-16	" " "	.....	7½	"	"	"
1-4	" " "	.....	10	"	"	"
5-16	" " "	.....	12½	"	"	"
3-8	" " "	.....	15	"	"	"
7-16	" " "	.....	17½	"	"	"
1-2	" " "	.....	20	"	"	"

Thickness of Boiler Iron.

No. 1 iron is 5-16 inch thick
No. 3 " nine thirty-seconds scant.
No. 4 " 1-4 inch.
No. 5 " seven thirty-seconds.
No. 7 " three-sixteenths.

Wire.

Weight of 100 Feet of Different Nos. of Iron, Brass, and Copper Wire.

No.	Iron, lbs.	Brass, lbs.	Copper, lbs.
1	25.92	28.64	29.61
2	22.58	24.95	25.79
3	19.46	21.51	22.23
4	16.58	18.33	18.94
5	13.94	15.40	15.92
6	11.52	12.73	13.15
7	9.33	10.31	10.65
8	7.29	7.96	8.38
9	6.60	7.21	7.59
10	4.96	5.42	5.71
16	1.05	1.14	1.20
20	0.32	0.34	0.37
25	0.11	0.12	0.13
30	0.38	0.41	0.43
36	0.042	0.046	0.049

To convert the decimals of a pound into ounces, multiply it by 16, thus: the weight of 100 feet of No. 20 iron wire = .32 × 16 = 5.12 ounces.

Weight of Angle Iron in Lbs. per Lineal Foot.

	Lbs.		Lbs. per ft.		Lbs.
1¼ × 1¼	1.8	4½ × 4½ × ½	14	6 × 4 × ⅝	20
1½ × 1½	2.7	4 × 4 × ½	12½	6 × 3½ × ⅝	18
1¾ × 1¾	3 3	3½ × 3½ × 7-16	9	5½ × 3½ × 9-16	15½
2 × 2	3.9	3 × 3 × ⅜	7	5 × 3 × 9-16	13¾
2¼ × 2¼	5	2½ × 2½ × 5-16	5	4½ × 3 × ½	11¾
2½ × 2½	6.5	2¼ × 2¼ × 5-16	4½	4 × 3½ × ½	11½
2¾ × 2¾	8.3	1¾ × 1¾ × ¼	3	4 × 3 × ½	11
3 × 3	10.4	1½ × 1½ × 3-16	2	3½ × 3 × 7-16	9½
3¼ × 3¼	11.7	1¼ × 1¼ × 3-16	1½	3 × 2½ × ⅜	6¼
3½ × 3½	14				

Weight of Washers per 100.

⅜	1¾ lbs.	¾	6¾ lbs.	1⅛	18¾ lbs.
½	2½ "	⅞	8½ "	1¼	24 "
⅝	4½ "	1	10¾ "	1½	30 "

Number of Cold Punched Nuts per 100 Pounds.

	Square.	Hexagon.		Square.	Hexagon.
⅜-in.	1951	3020	1-in.	109	100
½ "	812	800	1⅛ "	81	83
⅝ "	428	444	1¼ "	65	62
¾ "	248	261	1½ "	34	31
⅞ "	165	165			

Weight of Hot-Pressed Nuts.

Boonton Make.

Size No. to 100 Pounds.

	Square.	Hexagon.		Square.	Hexagon.
½-in.	1100	1250	1-in.	150	170
⅝ "	550	650	1⅛ "	98	110
¾ "	375	415	1¼ "	70	80
⅞ "	230	255	1½ "	45	55

Weight of Nuts and Bolt Heads, in Pounds.

Diameter of bolt in inches...	¼	⅜	½	⅝	¾	⅞
Weight of hexagon nut and head	.017	.057	.128	.267	.43	.73
Weight of square nut and head	.021	.069	.164	.320	.55	.88

Diam. of bolt, in inches.	1	1¼	1½	1¾	2	2½	3
Weight of hexagon nut and head	1.10	2.14	3.78	5.6	8.75	17	28.8
Weight of square nut and head	1.31	2.56	4.42	7.0	10.5	21	36.4

Table of Hexagon Nuts and Bolt Heads.

Diam. of Bolt in inches.	Width of Nut over angles.	Width of Nut over sides.	Thickness of Head.	Thickness of Nut.	Diam. of Bolt in inches.	Width of Nut over angles.	Width of Nut over sides.	Thickness of Head.	Thickness of Nut.
¼	7-16	⅜	¼	¼	1¼	2⅛	1⅞	1	1¼
5-16	⅝	9-16	5-16	5-16	1⅜	2⅜	2	1	1⅜
⅜	⅝	9-16	5-16	⅜	1½	2⅝	2¼	1⅛	1½
7-16	⅞	¾	7-16	7-16	1⅝	2⅞	2½	1¼	1⅝
½	⅞	¾	7-16	½	1¾	3	2⅝	1⅜	1¾
9-16	1	⅞	½	9-16	1⅞	3¼	2¾	1½	1⅞
⅝	1⅛	1	½	⅝	2	3½	3	1⅝	2
¾	1⅜	1 3-16	⅝	¾	2¼	3⅞	3⅜	1¾	2¼
⅞	1½	1 5-16	¾	⅞	2½	4⅜	3¾	2	2½
1	1¾	1½	⅞	1	2¾	4¾	4⅛	2¼	2¾
1⅛	1⅞	1⅝	⅞	1⅛	3	5¼	4½	2½	3

SCREWS.

Table of Whitworth's Screws.

(Angular Threads.)

Diam. in inches.	No. of Threads to inch.	Diam. in inches.	No. of Threads to inch.	Diam. in inches.	No. of Threads to inch.	Diam. in inches.	No. of Threads to inch.
3-16	24	1	8	2¼	4	4½	2⅞
¼	20	1⅛	7	2½	4	4¾	2¾
5-16	18	1¼	7	2¾	3½	5	2¾
⅜	16	1⅜	6	3	3½	5¼	2⅝
7-16	14	1½	6	3¼	3¼	5½	2⅝
½	12	1⅝	5	3½	3¼	5¾	2½
⅝	11	1¾	5	3¾	3	6	2½
¾	10	1⅞	4½	4	3		
⅞	9	2	4½	4¼	2⅞		

Angle of threads = 55°.
Depth of threads = pitch of screws.
⅙ of depth is rounded off at top and bottom.
No. of threads to the inch in square threads = ½ number of those in angular threads.

Weight of Cast-iron Balls and Solid Cylinders, in Pounds.

Diam. in inches...	1	2	3	4	5	6	7	8	9
Cast-iron Balls....	.136	1.10	3.70	8.7	17.1	29.5	47	70.	100.
Cast Iron Cylinder 1 foot long.....	2.4	9.9	21.9	39.0	61.0	89.0	120	156	198

STANDARD SCREW THREADS,

As recommended by a Committee of the Franklin Institute; Gauges as made by the Brown & Sharpe Manufacturing Company, of Providence, R. I.

Diameter of Screw.	Threads per inch.	Diameter at Root of Thd.	Width of Flat.	Diameter of Screw.	Threads per inch.	Diameter at Root of Thd.	Width of Flat.
1-4	20	.185	.0062	2¼	4½	1.962	.0277
5-16	18	.240	.0074	2½	4	2.176	.0312
3-8	16	.294	.0078	2¾	4	2.426	.0312
7-16	14	.344	.0089				
1-2	13	.400	.0096	3	3½	2.629	.0357
9-16	12	.454	.0104	3¼	3½	2.878	.0357
5-8	11	.507	.0113	3½	3½	3.100	.0384
3-4	10	.620	.0125	3¾	3	3.317	.0413
7-8	9	.731	.0138				
				4	3	3.567	.0413
1	8	.837	.0156	4¼	2⅞	3.798	.0435
1⅛	7	.940	.0178	4½	2¾	4.028	.0454
1¼	7	1.065	.0178	4¾	2⅝	4.256	.0476
1⅜	6	1.160	.0208				
1½	6	1.284	.0208	5	2½	4.480	.0500
1⅝	5½	1.389	.0227	5¼	2½	4.730	.0500
1¾	5	1.491	.0250	5½	2⅜	4.953	.0526
1⅞	5	1.616	.0250	5¾	3⅜	5.203	.0526
2	4½	1.712	.0277	6	2¼	5.423	.0555

Ramsey Wright and Foundry Co.

Rule for Computation of Weight of Cast and Wrought-Iron Bolts.—(*Horatio Allen.*)

Wrought-Iron Bolts.—Square the radius of the bolt, and multiply it by 10, and the product will give the weight, in lbs., per foot.

For Cast-Iron.—Subtract 2-27 or .074 of the result.

Capacity of Cistern, in Gallons, for each 10 inches in Depth.

Diam., in Ft.	Galls.	Diam., in Ft.	Galls.	Diam., in Ft.	Galls.	Diam., in Ft.	Galls.
2.	19.5	5.5	148.1	9.	396.56	15.	1,101.6
2.5	30.5	6.	176.25	9.5	461.4	20.	1,958.4
3.	44.6	6.5	206.85	10.	489.6	25.	3,059.9
3.5	59.97	7.	239.88	11.	592.4	30.	4,406.4
4.	78.33	7.5	275.4	12.	705.	35.	5,990.
4.5	99.14	8.	313.33	13.	827.4	40.	7,831.
5.	122.4	8.5	353.72	14.	959.6	45.	9,911.

Thickness of Sheet Brass, Silver, Gold, Zinc, etc.

By Birmingham Gauge for these Metals, which is the reverse of the Gauge used for Iron, etc., thickness No. 1 of this Gauge corresponding with thickness of No. 36 Iron Gauge.

No.	Thickness.	No.	Thickness.	No.	Thickness.	No.	Thickness.
	Inch.		Inch.		Inch.		Inch.
1	.004	10	.024	19	.064	28	.120
2	.005	11	.029	20	.067	29	.124
3	.008	12	.034	21	.072	30	.126
4	.010	13	.036	22	.074	31	.133
5	.013	14	.041	23	.077	32	.143
6	.014	15	.047	24	.082	33	.145
7	.015	16	.051	25	.095	34	.148
8	.016	17	.057	26	.103	35	.158
9	.019	18	.061	27	.113	36	.167

Tin Plate.

Names.	Marks.	Size in Inches.	No. in Box.	Thickness.
Common No. 1	1 C	10 × 14	225	1 C = 1-80 in.
" "	1 C	12 × 12	200	X 1-64 in.
" "	1 C	14 × 14	200	XX 1-55 in.
Cross No. 1	1 X	10 × 14	225	XXX 1-49 in.
" "	1 X	12 × 12	200	XXXX 1-44 in.
" "	1 X	14 × 14	200	
Common small double	S D C	11 × 15	200	
Cross " "	S D X	11 × 15	200	By Wire Gauge.
Common double	D C	12 × 17	100	1 C = No. 31
" "	D C	14 × 20	112	XX = No. 27
Cross double	D X	12 × 17	100	
" "	D X	14 × 20	112	

Sheet Copper.

Unit of size equal 4 feet by 2 feet.

70-lb. plate	= 3-16 in.	thick.
46½-lb. "	= 1-8	"
23-lb. "	= 1-16	"
11½-lb. "	= 1-32	"
6-lb. "	= 1-64	"

To cut a square of copper, tin, etc., so as to form a vessel of the greatest cubical capacity the sheet admits of:

Rule.—From each corner of the sheet, at right angles to the side, cut one-sixth part of the length of the side, and turn up the sides until the corners meet.

Weight of Cast-Iron Pipes.

Weight of a Lineal Foot of Cast-Iron Pipes in Lbs.

2 flanges = 1 foot of length in weight.

Bore inch.	Thickness of Metal.	Weight.	Bore inch.	Thickness of Metal.	Weight.	Bore inch.	Thickness of Metal.	Weight.
3	3/8	12.4	9	3/8	34.4	15	1	156.8
3	1/2	17.1	9	1/2	46.6	15	1 1/8	177.7
3	5/8	22.2	9	5/8	58.9	16	3/4	123.1
4	3/8	16.1	9	3/4	71.7	16	7/8	144.7
4	1/2	22.1	10	1/2	51.4	16	1	166.6
4	5/8	28.3	10	5/8	65.1	16	1 1/8	188.7
5	3/8	19.8	10	3/4	79.0	18	3/4	137.9
5	1/2	26.9	10	7/8	93.3	18	7/8	161.8
5	5/8	34.4	11	1/2	56.4	18	1	186.2
5	3/4	42.3	11	5/8	71.0	18	1 1/8	210.8
6	3/8	23.4	11	3/4	86.4	20	7/8	178.9
6	1/2	31.9	11	7/8	101.8	20	1	205.8
6	5/8	40.6	12	5/8	77.3	20	1 1/8	232.9
6	3/4	49.7	12	3/4	93.7	20	1 1/4	260.3
7	3/8	27.1	12	7/8	110.4	22	1	225.4
7	1/2	36.8	12	1	127.4	22	1 1/8	254.9
7	5/8	46.7	14	5/8	89.6	22	1 1/4	284.8
7	3/4	56.8	14	3/4	108.4	24	1	245.0
8	3/8	30.8	14	7/8	127.5	24	1 1/8	276.9
8	1/2	41.6	14	1	147.0	24	1 1/4	319.3
8	5/8	52.8	15	3/4	115.7			
8	3/4	64.3	15	7/8	136.1			

The average weight of a cast-iron water-pipe, 12 feet long, with flange, is found by adding the constant 35 to the product of the diameter multiplied by the thickness, multiplied by 127.

A tube of any diameter, and 12 feet long, has the same number of square feet of surface as it has inches in circumference.

Example—A 2-inch tube is 6.2832 inches circumference, and has 6.2832 square feet of surface if it is 12 feet long.

Weights and Dimensions of Gas Pipes.

Inside Diam. in Inches.	Outside Diam. in Inches.	Weight per foot in inches.
⅛	0.40	0.24
¼	0.55	0.42
⅜	0.67	0.56
½	0.84	0.85
¾	1.95	1.12
1	1.31	1.67
1¼	1.66	2.25
1½	1.9	2.69
2	2.37	3.66
2½	2.87	5.77
3	3.5	7.54
3½	4.0	9.05
4	4 5	10 72
4½	5.0	12.49
6	6 62	18.76
7	7.62	23.41
8	8.62	28.34
9	9.68	34.07
10	10.75	40.64

Weights and Dimensions of Lap-welded Iron Boiler Flues.

Outside Diameter.	Thickness W. G.	Lbs. weight per foot.
1¼	14	1.60
1½	14	1.68
1¾	13	1.80
2	13	2.08
2¼	13	2.25

Weight and Dimensions of Lap-welded Iron Boiler Flues—(Continued.)

Outside Diameter.	Thickness W. G.	Lbs. weight per foot.
2½	12	2.56
2¾	12	3.12
3	11	3.50
3¼	11	4.12
3½	10	5.15
3¾	10	5.28
4	10	5.54
5	9	7 0
6	8	10.0
7	8	12.0

To find Thickness of Wrought Iron Tubes.

To Resist External Pressure.

Pressure in lbs. per square inch × length of tube in feet, and diameter in inches; product divided by 161200, and the square root of the quotient = required thickness in inches.

For Internal Pressure.

Pressure in lbs. per square inch × radius of tube in inches, and divide by 8000 for thickness in inches.

Weight of Copper Tubes.

Find the surface of the tube or tubes in square feet; multiply the surface so found, as follows, for different thicknesses:

No. 10 copper	6.5	lbs. per square foot.
" 11 "	5.8	" " "
" 12 "	5.08	" " "
" 13 "	4.34	" " "
" 14 "	3.6	" " "
" 15 "	3.27	" " "

Surface of Tubes,

In square feet per lineal foot for diameters from ⅝ inch to 3 inches.

Bore.....	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½
Surface.....	.1636	.1963	.2291	.2618	.2945	.3270	.3599	.3927
Bore.....	1⅝	1¾	1⅞	2	2¼	2½	2¾	3
Surface.....	.4253	.4580	.4906	.5233	.5890	.6544	.7199	.7854

Weight per Foot Run of Lowmoor Rolled Tires.

Flange Tires.

5½ × 2	45 lbs.	er foot.
5½ × 2¼	49.58 "	"
5½ × 2½	54.16 "	"
5½ × 2¾	58.74 "	"
5¾ × 2¼	52.00 "	"
5¾ × 2½	56.78 "	"
6 × 2¼	54.50 "	"
6 × 2½	59.50 "	"
6 × 3	69.50 "	"

Plain Tires.

6 × 2	40.00 lbs.	per foot.
6 × 2¼	45.00 "	"
6 × 2½	50.00 "	"
6 × 3	60.00 "	"

Red Bottle Wax.

Common resin, 15 lbs.; tallow, 4 lbs.; red lead, 5 lbs. Mix with heat.

Weight and Strength of Round Ropes of Hemp and Wire.

Hemp		Iron Wire.		Steel Wire.		Equivalent Strength.	
Circumference.	Lbs. weight per fathom.	Circumference.	Lbs. weight per fathom.	Circumference.	Lbs. weight per fathom.	Working load per cwt.	Breaking strain per ton.
2¾	2	1	1	....	...	6	2
		1½	1½	1	1	9	3
3¾	4	1⅝	2	....	....	12	4
		1¾	2½	1½	1½	15	5
4½	5	1⅞	3	....	....	18	6
		2	3½	1⅝	2	21	7
5½	7	2⅛	4	1¾	2½	24	8
		2¼	4½	....	....	27	9
6	9	2⅜	5	1⅞	3	30	10
		2½	5½	....	....	33	11
6½	10	2⅝	6	2	3½	36	12
		2¾	6½	2⅛	4	39	13
7	12	2⅞	7	2¼	4½	42	14
		3	7½	....	....	45	15
7½	14	3⅛	8	2⅜	5	48	16
		3¼	8½	....	....	51	17
8	16	3⅜	9	2½	5½	54	18
		3½	10	2⅝	6	60	20
8½	18	3⅝	11	2¾	6½	66	22
		3¾	12	....	....	72	24
9½	22	3⅞	13	3¼	8	78	26
10	26	4	14	....	....	84	28
		4¼	15	3⅜	9	90	30
11	30	4⅜	16	....	....	96	32
		4½	18	3½	10	108	36
12	34	4⅝	20	3¾	12	120	40

Rule for Breaking Weight of Ropes.

Circumference in inches being represented by C.

Breaking weight in tons..... = 0.2 C^2 for hemp.
" " ..... = 1.5 C^2 " iron wire.
" " ..... = 2.5 C^2 " steel wire.

White ropes are 5 per cent. stronger than tarred.

Breaking weight of a good hemp rope is 6,400 lbs. per square inch; in use estimate one half.

Strength and Weight of Chains.

Chains.			Chain Cables.		
Diameter in inches.	Weight per fathom in lbs.	Proof strain in cwt.	Diameter in inches.	Weight per fathom in lbs.	Proof strain in cwt.
5-16	5½	25½	½	13¾	80
⅜	8	36¾	⅝	22	120
½	14	65½	¾	30	200
⅝	22	102	⅞	42	260
¾	32	147	1	55	360
⅞	43	200	1⅛	68	520
1	56	268	1¼	84	640
1⅛	71	334	1⅜	102	760
1¼	87	408	1½	120	880
1⅜	106	498	1¾	148	1,200
			2	180	1,600

Rule to find Breaking Weight of Chains.

Divide the square of the diameter of one bar of the link in sixteenths of an inch by 9, for short-linked chains, and by 8 for studded chains.

WEIGHTS AND MEASURES.

Long Measure.

inches						
12 =	1 foot					
36 =	3 =	1 yard				
72 =	6 =	2 =	1 fathom			
198 =	16½ =	5½ =	2¾ =	1 pole		
7920 =	660 =	220 =	110 =	40 =	1 furlong	
63360 =	5280 =	1760 =	880 =	320 =	8 =	1 mile

1 link = 7.92 inches
100 links = 1 chain = 66 feet = 22 yards
80 chains = 1 mile
1 geographical mile = 1.15 statute miles
" = 6075 feet nearly
Admiralty knot. . . . = 6080 feet
Lin. feet . . . . = .00019 miles
Lin. yards. . . . = .00057 miles.

Square Measure.

inches				
144 =	1 foot			
1296 =	9 =	1 yard		
39204 =	272¼ =	30¼ =	1 pole	
1568160 =	10890 =	1210 =	40 =	1 rood
6272640 =	43560 =	4840 =	160 =	4 = 1 acre

640 square acres = 1 square mile
Square inches = .007 square feet
Square yards = .0002067 acres
1 chain wide = 8 acres per mile
10 square chains = 1 acre.

Solid Measure.

inches		
1728 =	1 foot	
46656 =	27 =	1 yard

Cube inches = .00058 cube feet
Cube feet = .03704 cube yards
128 cubic ft. = 1 cord of wood
42 cubic feet = 1 ton of shipping.

Avoirdupois Weight.

drachms					
16 =	1 oz.				
256 =	16 =	1 lb.			
7168 =	448 =	28 =	1 quarter		
28672 =	1792 =	112 =	4 =	1 cwt.	
573440 =	35840 =	2240 =	80 =	20 =	1 ton

1 lb. = 14 oz. 11 dwt. 15½ gr. troy
1 oz. = 18 dwt. 5½ gr. troy
175 lbs. troy = 144 lbs. avoirdupois
lbs. avoirdupois = .009 cwt. (approximate)
= .00045 tons "

Troy Weight.

grains			
24 =	1 dwt.		
480 =	20 =	1 oz.	
5760 =	240 =	12 =	1 lb.

Apothecaries' Weight.

grains			
20 =	1 scruple		
60 =	3 =	1 drachm	
480 =	24 =	8 =	1 oz.
5760 =	288 =	96 =	12 = 1 lb.

United States Measure of Capacity.

cubic inches					
231	= 1 gallon				
462	= 2 =	1 peck			
1728	=	3.738 =	1 cubic foot		
2150.42	=	4	= 1.243 =	1 bushel	
8316	=			4½ =	1 barrel
46656	=				5.61 = 1 cubic yard.

United States Measure of Liquids.

cubic inches			
7.21	= 1 gill		
28.75	= 4	= 1 pint	
57.75	=	2	= 1 quart
231	=		4 = 1 gallon.

New York State Measure of Liquids.

6.912	cubic inches	= 1 gill.
27.648	"	= 1 pint.
55 296	"	= 1 quart.
221.184	"	= 1 gallon.

New York State Measure of Capacity.

8.64	cubic inches	= 1 gill.
34.56	"	= 1 pint.
69.12	"	= 1 quart.
276.48	"	= 1 gallon.
552.96	"	= 1 peck.
2211.84	"	= 1 bushel.

Statute gallon contains.....10 pounds of pure water.
" bushel " .....80 " "

United States gallons	=	231	cubic inches
Imperial (British) gallons	=	277.274	"
New York State liquid gallon	=	221.184	"
" " solid "	=	276 48	"
United States bushel	=	2150.42	"
Imperial "	=	2218 19	"
New York "	=	2211.84	"

U. S. gallon..... × 1.2023..... = Imperial gallon.
Imperial gallon... × .8318..... = U. S. "
" " ... × .7977..... = N. Y. State liquid gallon.
U. S. " ... × .9574..... = " " "
U. S. standard gal. = 8.3388 lbs. water; do. bush. = 77.627 do.

Cubic feet	× 7.48	=	U. S. gallons.
Cubic inches	× .004329	=	"
U. S. bushels	× 1.0315157	=	Imperial bushels.
Imperial bushels	× .969447	=	U. S. "
" "	× .99714	=	N. Y. bushels.
U. S. "	× 1.028561	=	" "

U. S. bushel is 18½ inches diameter inside, 19½ inches outside by 8 inches deep; when heaped, cone not to be less than 6 inches high, and to contain 2740.70 cubic inches for a true cone.

Imperial Wine Measure.

pints							
2 =	1 quart						
8 =	4 =	1 gallon					
336 =	168 =	42 =	1 tierce				
504 =	257 =	63 =	1½ =	1 hogshead			
672 =	336 =	84 =	2 =	1½ =	1 puncheon		
1008 =	504 =	126 =	3 =	2 =	1½ =	1 pipe	
2016 =	1008 =	252 =	6 =	4 =	3 =	2 =	1 tun.

Value of United States Coins.

Gold Coins—U. S. Standard.

Double Eagle	$20.00	516 grains.
Eagle	10.00	258 "
Half-Eagle	5.00	129 "
Three-Dollar piece	3.00	77.4 "
Quarter-Eagle	2.50	64.5 "
Dollar	1.00	25.8 "
Value per grain	0.0387596	1 "
Value per ounce	18.6046	480 "

Silver Coins—U. S. Standard.

One Dollar	100 cents.	384 grains.
Half-Dollar, or 5 Dimes	50 "	192 "
Quarter Dollar, or 2½ Dimes	25 "	96 "
One Dime	10 "	38.4 "

Half-Dime	5 cents.	19.2 grains.
Three-cent piece	3 "	11.52 "
Value per grain	0.260416	1 "
Value per ounce	125 cents.	480 "
Copper Cent	1 "	168 "
Value per grain	0.005952	1 "

The standard fineness of gold and silver coins is one weight of alloy to nine weights of pure metal. The alloy for gold is silver and copper; alloy for silver is copper.

FRENCH DECIMAL SYSTEM.

Long Measure.

French.		English.
Millimetre	=	0.0393 inch.
Centimetre	=	0.3937 "
Decimetre	=	3 9371 "
Metre	=	39 371 "
Decametre	=	32.809 feet.
Hectometre	=	328.09 "
Kilometre	=	1093.6389 yards.
Myriametre	=	6.2138 miles.

English.		French.
1 inch	=	.0254 metres.
1 foot	=	.30479 "
1 chain	=	20.116 "
1 mile	=	160.931 "

Square Measure.

French.		English.
Milliare	=	155.60 square inches.
Centiare	=	10.764 square feet.
Deciare	=	11.960 square yards.
Are	=	119.60 "

Are ..... = a square decametre.
Decare ..... = 1196.046 square yards.
Hectare ..... = 2.4712 acres.

Solid Measure.

French.	English.
Millistere	= 61.028 cubic inches.
Centistere	= 610 28 "
Decistere	= 3.5317 cubic feet.
Stere	= 35.317 "
"	= a cubic metre.
Decastere	= 13.080 cubic yards.
Hectostere	= 130.80 "

Weights.

French.	English.
Milligramme	= 0.0154 grains.
Centigramme	= 0.1543 "
Decigramme	= 1.5434 "
Gramme	= 15.434 "
Decagramme	= 154 34 "
Hectogramme	= 3.527 oz. avoirdupois.
Kilogramme	= 2.2048 lb. "
Myriagramme	= 22.048 " "
Quintal	= 1 cwt. 3 qrs. 24½ lbs.
Millier or bar	= 9 tons 16 cwt. 3 qrs. 12 lbs.
Gramme	= .0022 lbs. avoirdupois.
Kilogramme	= .01969 cwt.
Lbs. avoirdupois	= .4535 kilogrammes.

1 cwt. = 50.787 kilogrammes.
1 ton = 1015.965 "
1 ton English = 1.015965 ton French.
1 " " × 0.984 = 1 " "

Dry and Fluid Measure.

French.	English.
Millilitre	= 0.0610 cubic inches.
Centilitre	= 0.6103 " "

Ramapo Wheel and Foundry Co.

French.		English.
Decilitre	=	6.1028 cubic inches.
Litre	=	61.028 " "
"	=	1.761 imperial pints.
"	=	a cubic decimetre.

French.		English.
Decalitre	=	610.28 cubic inches.
"	=	2.2 imperial gallons.
Hectolitre	=	3.5317 cubic feet.
"	=	2.75 imperial bushels.
Kilolitre	=	35.317 cubic feet.
Myrialitre	=	353.171 "

Cubic inches = litres × 0,0163.
Gallons = litres × 4.543.

French Metre Reduced to United States Inches.

Metre.		Inches.	Millimetre.		Metre.		Inches.
.00317	=	1-8	1	=	.001	=	.03937
.00473	=	3-16	2	=	.002	=	.07874
.00634	=	1-4	3	=	.003	=	.11811
.00792	=	5 16	4	=	.004	=	.15748
.00951	=	3-8	5	=	.005	=	.19685
.01109	=	7-16	6	=	.006	=	.23622
.01268	=	1-2	7	=	.007	=	.2756
.01426	=	9-16	8	=	.008	=	.31497
.01585	=	5-8	9	=	.009	=	.35434
.01743	=	11-16	Centimetre.				
.01902	=	3-4	1	=	.01	=	.39371
.02060	=	13-16	2	=	.02	=	.78742
.02219	=	7-8	3	=	.03	=	1.18113
.02377	=	15-16	4	=	.04	=	1.5748
.02538	=	1	5	=	.05	=	1.9685
.05076	=	2	6	=	.06	=	2.3622
.07614	=	3	7	=	.07	=	2.756
.10152	=	4	8	=	.08	=	3.1497
.12690	=	5	9	=	.09	=	3 5434
.15228	=	6					
.17766	=	7					

Metre.		Inches.	Decimetre.		Metre.		Inches.
.20304	=	8	1	=	.1	=	3.9371
.22842	=	9	2	=	.2	=	7.8742
.25380	=	10	3	=	.3	=	11.8113
.27918	=	11	4	=	.4	=	15.7484
.30456	=	12	5	=	.5	=	19.6855
			6	=	.6	=	23.6226
			7	=	.7	=	27.5597
			8	=	.8	=	31.4976
			9	=	.9	=	35.4339

The Metre = 3.2809 feet.

Relative Value of Foreign Coins, fixed by law of the United States.

1 Pound Sterling	Great Britain	$4.84	
1 Shilling	" "	0.242	
1 Pound Sterling	Canada	4.00	
1 Dollar	Mexico	1.00	
1 Pagoda	India	1.84	
1 Real Vellon	Spain	0.05	
1 Real Platee	"	0.10	
1 Rupee Company	India	0.44	1-2
1 Franc	France	0.18	6-10
1 Franc	Belgium	0.18	6-10
1 Specie Dollar	Norway	1.06	
1 " "	Sweden	1.06	
1 Ducat	"	2.15	
1 Specie Dollar	Denmark	1.05	
1 Florin	Germany	0.40	
1 Guilder	Netherland	0.40	
1 Livre Tournoise	France	0.18	1-2
1 Milred	Portugal	1.12	
1 Milred	Azores	0.83	1-2
1 Marc Banco	Hamburg	0.35	
1 Rix Thaler	Prussia	0.69	
1 Rix Dollar	Bremen	0.78	3-4
1 Rouble, silver	Russia	0.75	
1 Florin	Austria	0.48	1-2

1 Ducat	Naples	$0.80
1 Ounce	Sicily	2.40
1 Tael	China	1.43
1 Livre	Leghorn	0.16

Foreign Road Measures, Compared with United States Yards.

1 U. S. mile = 5,280 feet, or 1,760 yards.

Places.	Measures.	U. S. Yards.
Arabia	Mile	2,148
Bohemia	"	10,137
China	Li	629
Denmark	Mile	8,244
England	Statute mile	1,760
"	Geo. mile	2,025
Flanders	Mile	6,869
France	League (marine)	6 075
"	" (common)	4,861
"	" (post)	4,264
Germany	Mile (long)	10,126
Hamburg	"	8,244
Hanover	"	11,559
Holland	"	6,395
Hungary	"	9,113
Ireland	"	3,038
Netherlands	"	1,093
Persia	Parasang	6,086
Poland	Mile (long)	8,101
Portugal	League	6,760
Prussia	Mile	8,468
Rome	"	2,025
Russia	Verst	1,167
Scotland	Mile	1,984
Spain	League	7,416
Sweden	Mile	11,700
Switzerland	"	9,153
Turkey	Berri	1,826

Richmond Iron.

FOREIGN MEASURES OF LENGTH, WEIGHT, AND LIQUID,
Compared with United States.

	LENGTH.			LIQUID.		WEIGHT.	
	Name of Measure.	No.=100.	Length in Ins.	Name of Measure.	Contents Cub. Ins.	Name of Weight.	No. = 100 lbs.
England ..	Foot.	100	12	Gallon.	277¼	Pound.	100
U. States.	Foot.	100	12	Gallon.	231	Pound.	100
Austria ...	Foot.	96.4	12.45	Eimoe.	3452	Pound.	80.96
Denmark .	Foot.	97.2	12.35	Ankor.	2355	Pound.	90.67
France....	Metre	39.47	39.37	Litre.	61.02	Kilo-gra me.	45.34
Holland ..	Foot.	107.7	11.14	Ankor.	2331	Pound.	45.34
Portugal..	Foot.	92.7	12.96	Almude.	1040	Pound.	98.82
Prussia....	Foot.	97.1	12.36	Eimor.	4200	Pound.	96.96
Russia ...	Foot.	87.2	13.75	Veddras	752	Pound.	110.78
Spain	Foot.	108	11.03	Arroba.	978	Pound.	98.57
Sweden...	Foot.	102.7	11.69	Eimor.	4794	Pound.	133.33

MENSURATION.

PROPERTIES OF THE CIRCLE.

Diameter $\times$ 3.14159 = circumference.
Diameter $\times$ .8862 = side of an equal square.
Diameter $\times$ .7071 = side of an inscribed square.
Diameter^2 $\times$ .7854 = area of circle.
Radius $\times$ 6.28318 = circumference.
Circumference $\div$ 3.14159 = diameter.

1st.—The circle contains a greater area than any plane figure, bounded by an equal perimeter or outline.

2d.—The areas of circles are to each other as the squares of their diameters.

3d.—Any circle whose diameter is double that of another contains four times the area of the other.

4th.—Area of a circle is equal to the area of a triangle whose base equals the circumference, and perpendicular equals the radius.

Mensuration of Surfaces.

Area of any parallelogram...	= base × perpendicular height.
Area of any triangle	= base × ½ perpendicular height.
Area of any circle	= diameter squared × .7854.
Area of sector of circle.....	= arc × ½ radius.
Area of segment of circle....	= area of sector of equal radius, less area of triangle.
Area of parabola	= base × ⅔ height.
Area of ellipse	= longest diameter × shortest diameter × .7854.
Area of cycloid	= area of generating circle × 3.
Area of any regular polygon.	= sum of its sides × perpendicular from its centre to one of its sides ÷ 2.
Surface of cylinder	= area of both ends + length × circumference.
Surface of cone.....	= area of base + circumference of base × ½ slant height.
Surface of sphere.....	= diameter^2 × 3.1415 = diameter × circumference.
Surface of frustrum.....	= sum of girt at both ends × ½ slant height + area of both ends.
Surface of cylindrical ring ...	= thickness of ring added to the inner diameter × by the thickness × 9.8698.
Surface of segment.....	= height of segment × whole circumference of sphere of which it is a part.

Mensuration of Solids.

Cylinder.	= area of one end × length.
Sphere	= cube of diameter × .5236.

Richmond Iron.

Segment of sphere.... = square root of the height added to three times the square of radius of base × by height and by .5236.

Cone or pyramid..... = area of base × ⅓ perpendicular height.

Frustrum of a cone.... = product of diameter of both ends + sum of their squares, × perpendicular height × .2618.

Frustrum of a pyramid = sum of the areas of the two ends + square root of their product, × by ⅓ of the perpendicular height.

Solidity of a wedge.... = area of base × ½ perpendicular height.

Frustrum of a wedge.. = ½ perpendicular height × sum of the areas of the two ends.

Solidity of a ring..... = thickness + inner diameter, × square of the thickness, × 2.4674.

Table of Polygons.

S = Side of polygon.
R = Radius of circumscribed circle.
r = Radius of inscribed circle.
A = Angle formed by the intersection of the sides.

Name.	No. of sides.	A	Area = S^2 ×	S = R ×	S = r ×
Trigon.....	3	60°	.4330	1.732	3.4641
Pentagon.....	5	108°	1.7205	1.1755	1.4536
Hexagon	6	120°	2.5980	1.0000	1.1547
Octagon	8	135°	4.8284	.7653	0.8284
Decagon.	10	144°	7.6942	.6180	.6498

Area of polygon = radius of inscribed circle × ½ number of sides × length of one side.

Table of Polyhedrons.

Name.	No. of Sides.	R = S ×	r = S ×	A = S² ×	C = S³ ×
Tetrahedron ..	4	0.6123	.2041	1.7320	0.1178
Hexahedron ..	6	.8660	.5000	6.0000	1.0000
Octahedron ...	8	.7071	.4082	3.4641	.4714
Dodecahedron	12	1.4012	1.1135	20.6457	7.6631
Icosahedron...	20	.9510	.7558	8.6602	2.1817

S = Length of linear edge of a side.
R = Radius of circumscribed circle.
r = Radius of inscribed circle.
A = Area of polyhedron.
C = Cube contents of polyhedron.

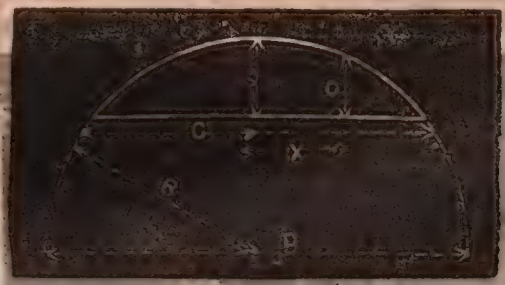
Segment Areas.

Area of segment of circle = diameter² × x (see table).

$\frac{V}{D}$ = the versed sine divided by the diameter of the circle, of which the segment is a part.

V/D	x	V/D	x	V/D	x	V/D	x	V/D	x
.01	.001329	.11	.047006	.21	.119898	.31	.207376	.41	.303187
.02	.003749	.12	.053385	.22	.128114	.32	.216666	.42	.313042
.03	.006866	.13	.059999	.23	.136465	.33	.226034	.43	.322928
.04	.010538	.14	.066833	.24	.144945	.34	.235473	.44	.332843
.05	.014681	.15	.073875	.25	.153546	.35	.244980	.45	.342783
.06	.019239	.16	.081112	.26	.162263	.36	.254551	.46	.352742
.07	.024168	.17	.088536	.27	.171090	.37	.264179	.47	.362717
.08	.029435	.18	.096135	.28	.180020	.38	.273861	.48	.382704
.09	.035012	.19	.103900	.29	.189048	.39	.283593	.49	.382700
.10	.040875	.20	.111824	.30	.188168	.40	.293370	.50	.392699

Segments of Circles.



V = Versed sin. R = Radius.
C = Semichord. O = Any ordinate.
X = Distance of ordinate from centre.

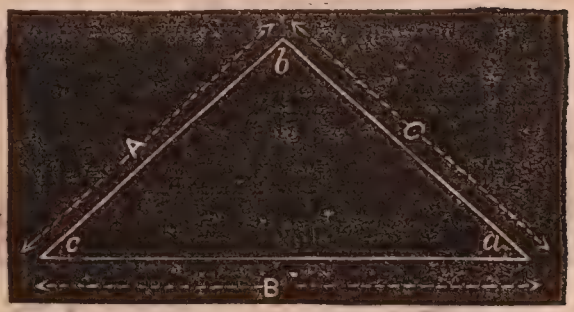
$$O = \sqrt{R^2 - X^2} - (R - V)$$

$$R = \frac{V^2 + C^2}{2V} \text{ or diameter } \frac{V^2 + C^2}{V}$$

$$V = R - \sqrt{R^2 - C^2}$$

$$\text{Area of segment} = \frac{4V}{3}\sqrt{(0.626\,V)^2 + C^2}$$

Properties of Triangles.



In right angled triangles = hypoth^2 = base^2 + perpend^2
base^2 = (hyp + perp) × (hyp—per)
perp^2 = (hy + ba) × (hy—ba)

Value of any Side A.

$$A = \frac{B \text{ Sin } a}{\text{Sin. } b} \qquad A = \frac{C \text{ Sin } a}{\text{Sin. } c}$$

$$A = \frac{B}{\text{Cos. } c + \text{Sin. } c \text{ Cot. } a} \qquad A = \frac{C}{\text{Cos. } b + \text{Sin. } b \text{ Cot. } a}$$

$$A = B \text{ Cos. } c + B \text{ Sin. } c \text{ Cot. } b$$

Value of any Angle.

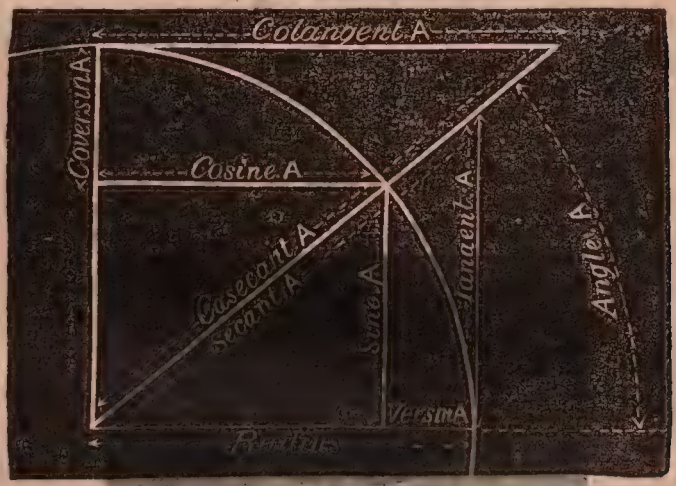
$$\text{Sin. } b = \frac{B \text{ Sin. } a}{A} \qquad \text{Sin. } b = \frac{B \text{ Sin. } a}{C}$$

$$\text{Sin. } b = \text{Sin. } (c + a)$$

$$\text{Sin. } b = \text{Sin. } c \text{ Cos. } a + \text{Cos. } c \text{ Sin. } a$$

Trigonometrical Expressions.

The diagram shows the different trigonometrical expressions in terms of the angle A.



Complement of an angle..... = its difference from 90°
Supplement..... = its difference from 180°

Trigonometrical Equivalents.

$\sqrt{(1-\text{Sin.}^2)} = \text{Cosine.}$	$\sqrt{(1-\text{Cosin.}^2)} = \text{Sine.}$
Sin. ÷ Tan. = Cosin.	Cosin. ÷ Cotan. = Sine.
Sin. × Cotan. = Cosin.	1 ÷ Cotan. = Tangent.
Sine ÷ Cos. = Tangent.	1 ÷ Sin. = Cosecant.
Cos. ÷ Sine = Cotangent.	1 ÷ Cosine = Secant.
$\text{Sin.}^2 + \text{Cos.}^2 = \text{Rad.}^2$	1 ÷ Cosecant = Sine.
$\text{Rad.}^2 + \text{Tan.}^2 = \text{Secant}^2$	1 ÷ Secant = Cosin.
1 ÷ Tan. = Cotangent.	Rad.—Cosin. = Versin.
	Rad.—Sin. = Coversin.

Definition of Terms used in Geometry.

A Circle is a plane figure bounded by a curved line, called the Circumference or Periphery.

A Diameter is a right line passing through the centre of a circle or sphere, terminated at each end by the periphery or surface.

An Arc is any part of the circumference of a circle.

A Chord is a right line joining the extremities of an arc.

A Segment of a circle is any part bounded by an arc and its chord.

The Radius of a circle is a line drawn from the centre to the circumference.

A Sector is any part of a circle bounded by an arc and its two radii.

A Semicircle is half a circle.

A Quadrant is a quarter of a circle.

A Zone is a part of a circle included between two parallel chords.

A Lune is the space between the intersecting arcs of two eccentric circles.

A Gnomon is the space included between the lines forming two similar parallelograms, of which the smaller is inscribed within the larger, having one angle in each common to both.

A Secant i the line running from the centre of the circle to the extremity of the tangent of the arc. Written *Sec.*

A Cosecant is the secant of the complement of an arc, or the line running from the centre of the circle to the extremity of the cotangen o the arc. Written *Cosec.*

A SINE of an arc is a line running from one extremity of an arc perpendicular to a diameter passing through the other extremity, and the sine of an angle is the sine of the arc that measures that angle. Written *Sin.*

The VERSED SINE of an arc or angle is the part of the diameter intercepted between the sine and the arc. Written *Versin.*

The COSINE of an arc or angle is the part of the diameter intercepted between the sine and the centre. Written *Cosin.*

The COVERSED SINE of an arc or angle is the part of the secondary radius intercepted between the cosine and the circumference. Written *Coversin.*

A TANGENT is a right line that touches a circle without cutting it. Written *Tan.*

A COTANGENT is the tangent of the complement of the arc. Written *Cot.*

The CIRCUMFERENCE of every circle is supposed to be divided into 360 equal parts, termed *Degrees;* each degree into 60 *Minutes*, and each minute into 60 *Seconds*, and so on.

The COMPLEMENT of an angle is what remains after subtracting the angle from 90 degrees.

The SUPPLEMENT of an angle is what remains after subtracting the angle from 180 degrees.

The VERTEX of a figure is its top or upper point.

The ALTITUDE, or height, of a figure is a perpendicular let fall from its vertex to the opposite side, called the base.

The MEASURE of an angle is an arc of a circle contained between the two lines that form the angle, and is estimated by the number of degrees in the arc.

LENGTH OF THE FOLLOWING ELEMENTS, RADIUS = 1.

	Angle 45°	Angle 60°		Angle 45°	Angle 60°
Sine	.707107	.866025	Cosecant	1.414214	1.1547
Cosine	.707107	.5	Tangent	1.	1.73205
Versed sine	.292893	.5	Cotangent	1.	.577349
Coversed sine	.292893	.133975	Chord	.765366	1.
Secant	1.414214	2.	Arc	.785398	1.0472

NATURAL.—SINES, ETC.

Deg.	Sine.	Cover.	Cosecnt.	Tangt.	Cotang.	Secant.	Vrsn.	Cosin.	Deg.
0	.00	1.00000	Infinite.	.0	Infinite.	1.00000	.0	1.00000	90
1	.01745	.98254	57.2986	.01745	57.2899	1.00015	.0001	.99984	89
2	.03489	.96510	28.6537	.03492	28.6362	1.00060	.0006	.99939	88
3	.05233	.94766	19.1073	.05240	19.0811	1.00137	.0013	.99862	87
4	.06975	.93024	14.3355	.06992	14.3006	1.00244	.0024	.99756	86
5	.08715	.91284	11.4737	.08748	11.4300	1.00381	.0038	.99619	85
6	.10452	.89547	9.5667	.10510	9.5143	1.00550	.0054	.99452	84
7	.12186	.87813	8.2055	.12278	8.1443	1.00750	.0074	.99254	83
8	.13917	.86082	7.1852	.14054	7.1153	1.00982	.0097	.99026	82
9	.15643	.84356	6.3924	.15838	6.3137	1.01246	.0123	.98768	81
10	.17364	.82635	5.7587	.17632	5.6712	1.01542	.0151	.98480	80
11	.19080	.80919	5.2408	.19438	5.1445	1.01871	.0183	.98162	79
12	.20791	.79208	4.8097	.21255	4.7046	1.02234	.0218	.97814	78
13	.22495	.77504	4.4454	.23086	4.3314	1.02630	.0256	.97437	77
14	.24192	.75807	4.1335	.24932	4.0107	1.03061	.0297	.97029	76
15	.25881	.74118	3.8637	.26794	3.7320	1.03527	.0340	.96592	75
16	.27563	.72436	3.6279	.28674	3.4874	1.04029	.0387	.96126	74
17	.29237	.70762	3.4203	.30573	3.2708	1.04569	.0436	.95630	73
18	.30901	.69098	3.2360	.32491	3.0776	1.05146	.0489	.95105	72
19	.32556	.67443	3.0715	.34432	2.9042	1.05762	.0544	.94551	71
20	.34202	.65797	2.9238	.36397	2.7474	1.06417	.0603	.93969	70
21	.35836	.64163	2.7904	.38386	2.6050	1.07114	.0664	.93358	69
22	.37460	.62539	2.6694	.40402	2.4750	1.07853	.0728	.92718	68
23	.39073	.60926	2.5593	.42447	2.3558	1.08636	.0794	.92050	67
24	.40673	.59326	2.4585	.44522	2.2460	1.09463	.0864	.91354	66
25	.42261	.57738	2.3662	.46630	2.1445	1.10337	.0936	.90630	65
26	.43837	.56162	2.2811	.48773	2.0503	1.11260	.1012	.89879	64
27	.45399	.54600	2.2026	.50952	1.9626	1.12232	.1089	.89100	63
28	.46947	.53052	2.1300	.53170	1.8807	1.13257	.1170	.88294	62
29	.48480	.51519	2.0626	.55430	1.8040	1.14335	.1253	.87461	61
30	.50000	.50000	2.0000	.57735	1.7320	1.15470	.1339	.86602	60
31	.51503	.48496	1.9416	.60086	1.6642	1.16663	.1428	.85716	59
32	.52991	.47008	1.8870	.62486	1.6003	1.17917	.1519	.84804	58
33	.54463	.45536	1.8360	.64940	1.5398	1.19236	.1613	.83867	57
34	.55919	.44080	1.7882	.67450	1.4825	1.20621	.1709	.82903	56
35	.57357	.42642	1.7434	.70020	1.4281	1.22077	.1808	.81915	55
36	.58778	.41221	1.7013	.72654	1.3763	1.23606	.1909	.80901	54
37	.60181	.39818	1.6616	.75355	1.3270	1.25213	.2013	.79863	53
38	.61566	.38433	1.6242	.78128	1.2799	1.26901	.2119	.78801	52
39	.62932	.37067	1.5890	.80978	1.2348	1.28675	.2228	.77714	51
40	.64278	.35721	1.5557	.83909	1.1917	1.30540	.2339	.76604	50
41	.65605	.34394	1.5242	.86928	1.1503	1.32501	.2452	.75470	49
42	.66913	.33086	1.4944	.90040	1.1106	1.34563	.2568	.74314	48
43	.68199	.31800	1.4662	.93251	1.0723	1.36732	.2686	.73135	47
44	.69465	.30534	1.4395	.96568	1.0355	1.39016	.2806	.71933	46
45	.70710	.29289	1.4142	1.00000	1.0000	1.41421	.2928	.70710	45
	Cosin.	Versin.	Secant.	Cotang.	Tangt.	Cosecnt.	Covn.	Sine.	

Cycloidal Curve.

Length of curve..... = diameter of generating circle × 4.
Length of base A B.... = circumference of generating circle.
Area of cycloid..... = area of generating circle × 3.

Construction of the Cycloidal Curve.

On the line A B, lay off any point 1, 2, 3, 4, etc., draw perpendicular lines at each point, and on each describe circles equal to the generating circle.

On the circumference of the circle at 1 lay off 1.1′ = A.1.
" " " 2 " 2.2′ = A.2.
" " " 3 " 3.3′ .. A.3.
and so on; the points 1′, 2′, 3′, 4′, 5′, are points of the curve.

To Construct an Ellipse by Ordinates.

Divide the semi-transverse axis into 10 equal parts, and draw ordinates. The length of these ordinates = the semi-conjugate axis C, multiplied by the respective numbers on each ordinate in the diagram.

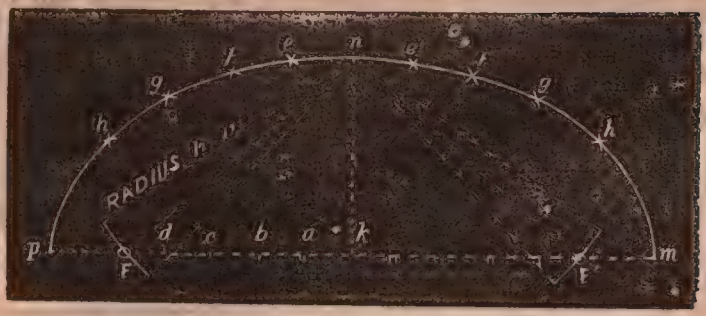
Ellipse.

To Calculate any Ordinate.

Let T = Semi-transverse axis.
C = Semi-conjugate axis.
k = The length of any ordinate.
X = Distance of the ordinate from the centre.

$$k = \sqrt{C^2 - \left(\frac{C\,X}{T}\right)^2}$$

Area of an ellipse = T C 3.1416
Periphery of an ellipse = (T + C × 3.1416).



To Draw an Ellipse.

From *n*, with radius *n* F = semi-transverse axis *k m*, draw a circle, cutting the transverse axis at F F′. F F′ are the foci of the ellipse.

On the transverse axis lay off any points, *a b c d*, between the foci, and

From F with radius = *p a* describe a portion of a circle at *e*.

From F′ with radius = *m a* describe a portion of a circle at *e*.

The curve will pass through the intersection of these circles.

In like manner *f* is described from the foci with the radii = *p b* and *m b* respectively

g with radii = *p c* and *m e* respectively

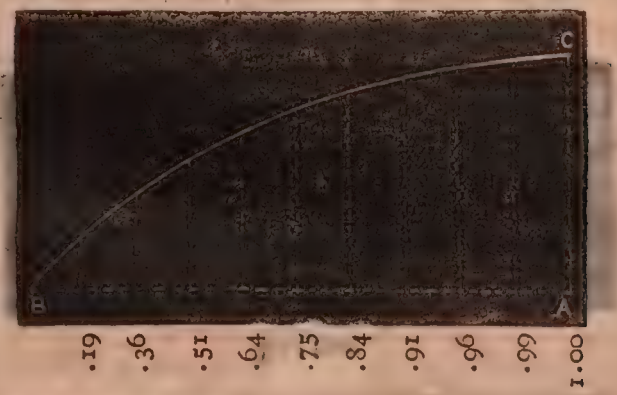
h with radii = *p d* " *m d* "

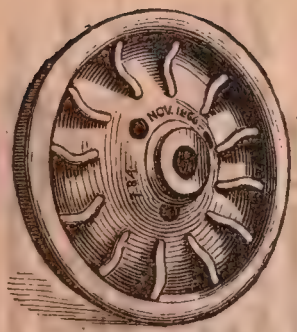
e′ with radii = *m a* " *p a* "

f′ with radii = *m b* " *p b* " etc.

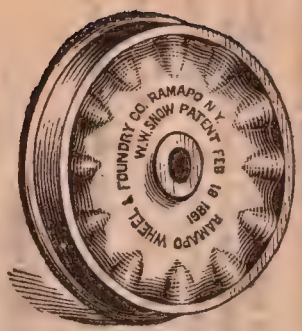
Construction of Parabolic Curve.

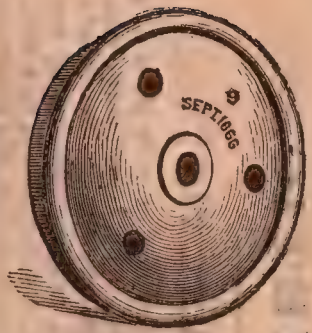
Divide the ordinate A B into 10 equal parts and raise perpendiculars, the length of which will be determined by multiplying the abscissa, A *c*, by the respective number on each perpendicular in the diagram.





WASHBURN PATTERN.





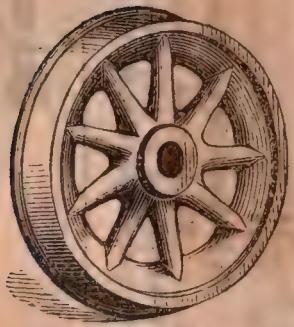
W. W. SNOW'S PATTERN.

CAR WHEELS,

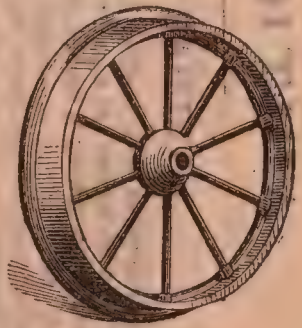
MADE BY

Ramapo Wheel and Foundry Co.,

RAMAPO, N. Y.



HOLLOW SPOKE.



CONSTRUCTION.

ARITHMETIC.

VULGAR FRACTIONS.

A FRACTION is a broken number, or one or more parts of a UNIT, as 36 inches are equal to 1 yard; here 1 yard is the unit, 36 inches its parts; 9 inches, therefore, are the one fourth of a yard, for 9 is the one-fourth of 36, and is expressed by two numbers placed one above the other, as 9 inches = $\frac{1}{4}$ of a yard.

The *upper* number is termed the NUMERATOR, the *lower* the DENOMINATOR.

A fraction denotes division, and its value is equal to the quotient arising from dividing the numerator by the denominator.

Fractions are PROPER, as $\frac{3}{4}$; IMPROPER, as $\frac{3}{1}$; MIXED, as $4\frac{3}{4}$; COMPOUND, as $\frac{1}{4}$ of $\frac{2}{3}$, or COMPLEX, as $\frac{\frac{1}{2}}{7}$, or $\frac{\frac{1}{2}}{\frac{3}{4}}$, or $\frac{4\frac{1}{2}}{6}$, the complex having a fraction in either numerator, denominator, or in both.

REDUCTION OF VULGAR FRACTIONS.

To Reduce Fractions to their Lowest Terms.

RULE—Divide both terms by any number that will divide them without a remainder, and the quotient again as before, and so on till no number greater than 1 will divide them.

Ex., as $\frac{24}{18} = \frac{12}{9} = \frac{4}{3}$.

To Reduce a Whole Number to an Equivalent Fraction having a Given Denominator.

RULE—Multiply the whole number by the given denominator, and place the product over the said denominator.

Ex.—Reduce 6 to a fraction whose denominator will be 12.

$$\frac{6 \times 12}{12} = \frac{72}{12}.$$

To Reduce a Mixed Number to an Improper Fraction.

RULE—Multiply the whole number by the denominator of the fraction, and to the product add the numerator, and place the sum above the denominator.

Ex.—Reduce $8\frac{5}{6}$ and $7\frac{4}{5}$ to improper fractions. $8\frac{5}{6} = \frac{53}{6}$ and $7\frac{4}{5} = \frac{39}{5}$.

To Reduce a Compound Fraction to an Equivalent Simple One.

RULE—Multiply all the numerators together for a numerator, and all the denominators for a denominator,

Ex.—Reduce ½ of ¾ of a pound to a simple fraction. ½ of ¾ = ⅜.

To Reduce Complex Fractions to Simple Ones.

RULE.—Reduce the mixed numbers to improper fractions; then multiply the numerator of each by the denominator of the other.

Ex.—Reduce $\frac{2\frac{7}{8}}{1\frac{3}{4}}$ to a simple fraction.

$2\frac{7}{8} = \frac{23}{8}$ and $1\frac{3}{4} = \frac{7}{4}$, then $\frac{23}{8} \times \frac{4}{7} = \frac{92}{56} = \frac{23}{14}$.

To Reduce Fractions of Different Denominations to Equivalent Ones, having a Common Denominator.

RULE—Multiply each numerator by all the denominators except its OWN, for the new numerator, and all the denominators together for a common denominator.

Ex.—Reduce $\frac{3}{4}$ $\frac{5}{8}$ $\frac{3}{6}$ to a common denominator.

$$\left.\begin{array}{l} 3 \times 8 \times 6 = 144 \\ 5 \times 4 \times 6 = 120 \\ 3 \times 4 \times 8 = 96 \\ \hline 4 \times 8 \times 6 = 192 \end{array}\right\} ; \frac{144}{192} ; \frac{120}{192} ; \frac{96}{192}.$$

ADDITION OF VULGAR FRACTIONS.

RULE—If the fractions have a common denominator, add all the numerators together and place the sum over the denominator. Reduce compound and complex fractions to simple ones, and all of them to their least common denominator.

Ex.—Add $\frac{1}{4}$ and $\frac{3}{4} = \frac{4}{4} = 1$.

Subtraction of Vulgar Fractions.

Rule—Prepare the fractions as in Addition, and subtract one numerator from the other; set the remainder over the common denominator.

Ex.—Subtract $\frac{5}{9}$ from $\frac{7}{8}$ $\left.\begin{array}{l} 5 \times 8 = 40 \\ 9 \times 7 = 63 \end{array}\right\} \frac{63}{72} - \frac{40}{72} = \frac{23}{72}$

$9 \times 8 = 72$

Multiplication of Vulgar Fractions.

Rule.—Prepare the fractions as for other operations.

Multiply all the numerators together for a new numerator, and all the denominators for a new denominator.

Ex.—Multiply

$\frac{3}{4}$ of 6 by $\frac{4}{5}$. $\frac{3}{4}$ of $6 = \frac{18}{4} \times \frac{4}{5} = \frac{72}{20} = 3\frac{12}{20} = 3\frac{3}{5}$

or multiply $\frac{3}{4} \times \frac{5}{8} = \frac{15}{32}$.

Division of Vulgar Fractions.

Rule—Prepare the fractions as before; then divide the numerator by the numerator, and the denominator by the denominator, if they will exactly divide; if not, invert the terms of the divisor and multiply the dividend by it, as in multiplication.

Ex.—Divide $\frac{20}{6}$ by $\frac{2}{3}$. $\frac{20}{6} \div \frac{2}{3} = \frac{10}{2} = 5$.

Ex.—Divide $\frac{17}{6}$ by $\frac{2}{5} = \frac{17}{6} \times \frac{5}{2} = \frac{85}{12} = 7\frac{1}{12}$

DECIMAL FRACTIONS.

A decimal fraction is that which has for its denominator a unit, with as many cyphers annexed as the numerator has places. It is usually expressed by setting down the numerator only, with a dot (.) before it. Thus, $\frac{7}{10}$ is .7; $\frac{42}{100}$ is .42; $\frac{345}{1000}$ is .345. When there is a deficiency of figures in the nu-

merator, prefix cyphers to make up as many places as there are cyphers in the denominator.

A cypher placed at the left hand of a decimal *decreases* its value in a tenfold ratio, by removing it further from the decimal point; as .5, .05, .005, are equal to $\frac{5}{10}$, $\frac{5}{100}$, $\frac{5}{1000}$. But annexing a cypher to any decimal does not alter its value; as .5, .50, .500, are equal to $\frac{1}{2}$.

Addition of Decimals.

Rule—Place the numbers so that the decimal points shall be directly over each other; add as in whole numbers, and place decimal point *directly* below the other points.

Ex.—Add 10.30 and 150.780.

```
 10.30
150.780
-------
161 080
```

Subtraction of Decimals.

Rule—Place the numbers as for Addition, according to their values; subtract as in whole numbers, and point as for Addition.

Ex.—Subtract 8.5 from 16.004.

```
16.004
 8.5
------
 7.504
```

Multiplication of Decimals.

Rule—Place the factors under each other and multiply together as in whole numbers; point off as many figures in the product (*counting from right to left*) as there are decimal places in both factors. If there are not so many figures in the product, supply the deficiency by prefixing cyphers.

Ex.—Multiply 1.4 by 3.4.

```
  1.4
  3.4
-----
   56
  42
-----
 4.76
```

Or, 1.30 by .007.

```
 1.30
 .007
-----
.00910
```

Division of Decimals.

Rule—Divide as in whole numbers, and point off in the quotient as many places for decimals as the decimal places in the dividend exceed those of the divisor; but if there are not so many places, supply the deficiency by prefixing cyphers.

Ex.—Divide 46 by 4.3. 4.3)46 000(10.69+

Reduction of Decimals.

To Reduce a Vulgar Fraction to its Equivalent Decimal.

Rule—Divide the numerator by the denominator, annexing cyphers to the numerator, as may be required.

Ex.—Reduce $\frac{3}{5}$ to a decimal. 5)30
.6

To ascertain the Value of a Decimal in Terms of a Lower Denomination.

Rule—Multiply the decimal by the number of parts in the next lower denomination, and cut off as many places for a remainder, *to the right hand*, as there are places in the given decimal; multiply that remainder by the parts in the next lower denomination, again cutting off for a remainder, and so on through all parts of the integer.

Ex.—What is the value of .500 of a yard?

.500
3
feet, 1.500
12
ins. 6.000 = 1 ft. 6 inches.

To Reduce Decimals to Equivalent Decimals of a Higher Denomination.

Rule—Divide by the number of parts in the next higher denomination, continuing the process as far as required.

Ex.—Reduce 18 ins. to the decimal of a yard. 12)18
3)1.5
.5

DUODECIMALS.

In duodecimals the dimensions are taken in feet, inches and twelfths of an inch.

RULE—Set the dimensions to be multiplied one under the other, feet under feet, inches under inches, &c. Multiply each term of the multiplicand, beginning at the lowest, by the feet in the multiplier, and set the result of each immediately under its corresponding term, carrylng 1 for every 12 from one term to the other. In like manner multiply all the multiplicand by the inches of the multiplier, and then by the twelfth part, setting the results of each term one place farther to the right hand for every multiplier. The sum of the products is the result.

Ex.—Multiply 1 foot 2 inches by 1 foot 1 inch.

Feet.	Ins.	
1	2.	
1	1	
1	2	
	1	2
1 foot	3 ins.	2 twelfths of an inch.

EQUATION OF PAYMENTS.

RULE—Multiply each sum by its time of payment in days, and divide the sum of the products by the sum of the payments.

SIMPLE INTEREST.

To Compute the Interest on any Given Sum for One or More Years.

RULE—Multiply the given sum or principal by the rate per cent. and the number of years; point off two figures to the right of the product, and the result will give the interest in dollars and cents for one year.

When the Time is Less than One Year.

RULE—Proceed as above, multiplying by the number of months or days, and divide by 12 for months and 365 or 366 for days.

The interest on any sum at 6 per cent. = 1 per cent. for two months.

The interest on any sum at 5 per cent. $\frac{1}{6}$th less than at 6 per cent.

The interest at 7 per cent. $\frac{1}{6}$th greater than 6 per cent.

COMPOUND INTEREST.

Haswell.

If any principal be multiplied by the amount (in the following table) opposite the years and under the rate per cent., the sum will be the amount of that principal at compound interest for the time and rate taken.

Years.	5 per ct.	6 per ct.	7 per ct.	Years.	5 per ct.	6 per ct.	7 per ct.
1	1.05	1.06	1.07	13	1.88564	2.13292	2.40985
2	1.1025	1.1236	1.1449	14	1.97993	2.26090	2,57853
3	1.15762	1.19101	1.22504	15	2.07892	2.39655	2.75903
4	1.2155	1.26247	1.3108	16	2.18287	2.54035	2.95216
5	1.27698	1.33822	1.40255	17	2.29201	2.69277	3.15881
6	1.34	1.41851	1.50073	18	2.40661	2.85433	3.37994
7	1.4071	1.50363	1.60578	19	2.52695	3.02559	3.61654
8	1.47745	1.59384	1.71819	20	2.65329	3.20713	3.8697
9	1.55132	1.68947	1 83846	21	2.78596	3,39956	4.14057
10	1.62889	1.79084	1.96715	22	2,92526	3,60353	4.43041
11	1.71033	1.89829	2.10485	23	3.07152	3.81974	4.74054
12	1.79585	2.01219	2.25219	24	3.22509	4.04873	5.07238

TABLE SHOWING VALUE OF CURRENCY WITH GOLD AT A PREMIUM.

When Gold is sold for Currency at	Percentage of Discount on U. S. Legal Currency is	$100 in Currency will buy in Gold	When Gold is sold for Currency at	Percentage of Discount on U. S. Legal Currency is	$100 in Currency will buy in Gold
105	4.77	95.23	210	52.38	47.62
110	9.10	90.90	215	53.40	46.51
115	13.05	86.95	220	54.55	45.45
120	16.67	83.33	225	55.66	44.41
125	20.00	80.00	230	56.62	43.18
130	23.03	76.92	240	58.33	41.67
135	25.93	74.07	250	60.00	40.00
140	28.58	71.42	260	61.54	38.48
145	31.04	68.96	270	62.97	37.61
150	33.34	66.66	280	64.29	35.71
155	35.49	64.51	290	65.52	34.48
160	37.50	62.50	300	66.67	33.33
165	39.40	60.69	400	75.00	25.00
170	41.18	58.82	500	80.00	20.00
175	42.86	57.14	600	88.34	16.66
180	44.45	55.55	700	85.71	14.29
185	45.95	54.05	800	87.59	12.50
190	47.37	52.63	900	88.99	11.11
195	48.72	51.28	1,000	90.00	10.00
200	50.00	50.00	5,000	98.00	2.00
205	51.22	48.78	10,000	99.00	1.00

RULE, to find value of currency at any given premium of gold. Divide 100 by 100 added to the premium of gold—quotient equal value of currency.

RULE to find percentage of discount at a given premium of gold. Subtract the amount which $100 in currency will buy in gold from $100. Answer, equal discount, or percentage of depreciation of the currency.

INTEREST.

To calculate interest at 6, 7, 8, 9, and 10 per cent. per annum.

RULE—When the rate is 6 per cent., multiply principal by number of days, and divide by 6083—quotient will be answer in dollars and cents ready pointed off. Example: What is the interest on $125.25 for 1 year 5 months 9 days at 6 per cent. No. of days = 527 × 125.25 ÷ 6083 = $10.85 answer.

RULE—When rate is 7 per cent., multiply principal by number of days, and divide by 5214.

RULE—When rate is 8 per cent., multiply principal by number of days, and divide by 4563.

RULE—When rate is 9 per cent., multiply as above, and divide by 4055.

RULE—When rate is 10 per cent., multiply as above, and divide by 3650.

To find divisor for any given rate of interest—multiply 365 by 100, and divide the product by the given rate of interest.

TO CONVERT FEDERAL CURRENCY INTO STERLING MONEY.

Multiply by 9 and divide by 40.

TO CONVERT STERLING MONEY INTO FEDERAL CURRENCY.

RULE—Multiply the number of pounds by 40, and double the shillings and pence, which add. Divide the product by 9, and you have the amount required. Should there be a remainder, each unit is 6 pence sterling or 11 cents, which also add.

REASON WHY:

You multiply by 40, because there are 40 sixpences sterling in a pound, and you divide by 9, because nine sixpences compose a dollar.

STERLING INTEREST TABLE.

To compute interest on Sterling money, from ½ to 6 per cent., on any amount, for any given number of days, to the fractional part of a penny.

RULE—Multiply the principle amount by the number of days, and divide the product by the factor opposite the rate of interest.

At ½	per cent. by....	73.000	At 4	per cent. by....	9.125
" 1	"	36.500	" 4½	"	8.111
" 1½	"	24.333	" 5	"	7.300
" 2	"	18.250	" 5½	"	6.637
" 2½	"	14.600	" 6	"	6.083
" 3	"	12.167			

STERLING INTEREST TABLE—Continued.

Example.

Wanted, interest, at 2½ per cent., on £100 12*s.* 0*d.*, for 365 days.

```
                    £100 12 0
                        365
                    ---------
                14600)36500(£2
                      29200
                      -----
                       7300
                         20
                      -----
                14600)146012(10s.
                      146000
                      ------
                          12 × 365 = 4380
                                     12
                                  -------
                          14600)52560(3
                                43800
                                -----
                                 8760
                                    4
                                -------
£2 10s. 3½d.                    14600)35040(½
```

REBATE OR DISCOUNT.

To Find Discount upon Money paid Before it is Due.

Rule—Multiply the amount by the rate per cent., and by the time, and divide the product by the sum of the product oi he rate per cent., and the time added to 100.

Ex.—What is the discount upon $10,000 for 3 years, 5 months, and 15 days, at 6 per cent.? 3 yrs. 5 mos. 15 days=3.4574 yrs.

$$\frac{10{,}000 \times 6 \times 3.4574}{6 \times 3.4574 + 100} = \frac{207444\ 00}{120.7444} = \$1718\ 04$$

INTEREST AND DISCOUNT.

To Ascertain the Principal, the Time, Rate per Cent and Interest being Given.

Rule—Divide the given interest by the interest of $1.00, for the given rate and time.

Ex.—What sum of money, at 6 per cent., will, in 14 months, produce $14?

Interest on $1, at 6 per ct., for 12 mos.=6
Interest on $1, at 6 per ct., for 2 mos.=1 } 14÷.07=200 dolls.

To Ascertain the Rate per Cent., the Principal, Interest, and Time being Given.

Rule—Divide the given interest by the interest of the given sum, for the time, at 1 per cent.

Ex.—If $32.66 was the discount on a note of $400, for 14 months, what was that per cent.? Interest on $400, for 14 months, at 1 per cent. = 4.66; then, 32.66 ÷ 4.66 = 7 per cent.

To Ascertain the Time, the Principal, Rate per Cent., and Interest being Given.

Rule—Divide the given interest by the interest of the given sum, at the rate per cent., for one year.

Ex.—In what time will $1.08 produce $11.34, at 7 per cent.? The interest on 108 for 1 year = 7.56.

11.34 ÷ 7.56 = 1.5 years.

PROPERTIES OF NUMBERS.

1. A Prime Number is that which can only be divided without a remainder by 1 or unity.
2. A Composite Number is that which can be divided by some number greater than unity.
3. A Perfect Number is that which is equal to the sum of all its divisors or liquot arts, as $6 = \frac{6}{6}, \frac{6}{3}, \frac{6}{2}$.
4. If the sum of the digits constituting any number, be divisible by 3 or 9, the whole is divisible by them.
5. A square number cannot terminate with an *odd* number of ciphers.
6. No square number can terminate with two equal digits except two ciphers or two fours.
7. No number the last digit of which is 2, 3, 7, or 8, is a square number

Simple Rules to Facilitate Calculation.

To Divide by 10, 100, 1,000, *etc.* :

Rule—Cut off as many figures from the right hand of the dividend as there are ciphers in the divisor. The remaining figures of the dividend will be the quotient, and those cut off the remainder.

Example—Divide 253,711,842 by 10,000. Ans. $25,374 \frac{1842}{10,000}$

To Divide by 5, 25, *or* 125 :

Rule—Multiply the dividend by 2, 4, or 8, and divide the product by 10, 100, or 1,000.

Example—Divide 69,250 by 25.

```
69,250
     4
------
2,770|00   Ans. 2,770
```

To Multiply by 3⅓, 33⅓, 333⅓, *etc.* :

Rule—Annex as many ciphers to the multiplicand as there are 3s in the integral part of the multiplier ; then take ⅓ of the number thus produced ; the result will be the answer desired.

Example—Multiply 674 by 33⅓.

```
3 67,400
--------
Ans. 22,466⅔
```

If the Multiplier is 6⅔, 66⅔, 666⅔, *etc.* :

Proceed by the same rule, and multiply the answer by 2.

To Divide by 3⅓, 33⅓, 333⅓, *etc.* :

Rule—Multiply the dividend by 3, divide the product by 10, 100, or 1,000, and the result will be the true quotient.

Example—Divide 22,466⅔ by 33⅓.

```
22,466⅔
      3
--------
674|00   Ans. 674
```

Notes.

1*st.* Any number ending in 0, or an even number, as 2, 4, 6, etc., may be divided by 2.

2*d.* Any number ending in 5 or 0, may be divided by 5.

3*d.* Any number ending in 0, may be divided by 10.

4*th.* When the *two* right hand figures are divisible by 4, the *whole* number may be divided by 4.

5*th.* If the *three* right hand figures of any number are divisible by 8, the whole is divisible by 8.

6*th.* Numbers ending with 00, 25, 50, 75, are all divisible by 25.

MEAN PROPORTION.

A mean proportion is one whose middle terms (or means), are equal quantities; thus, 9 : 3 : : 3 : 1.

RULE.—Multiply the two extreme numbers together, and extract the square root of their product.

Ex.—What is the mean proportionate velocity to 15 and 40?

$$15 \times 40 = 600, \text{ and } \sqrt{600} = 24.49 +.$$

RULE OF THREE.

The *Rule of Three* teaches how to find a fourth proportional term to three given numbers.

The Rule of Three is either *direct* or *inverse*. When *more* requires *more*, or *less* requires *less*, it is *direct*. Thus, if 5 mules cost $800, what will 10 mules cost? the statement must be—

5 : 10 : : 800 : 4th term = $1,600,

the proportion being *direct*.

When more requires *less*, or less requires *more*, the rule is *inverse*.

Thus, if 3 men lay a wall in 5 days, in how many days will 4 men do the same work? the statement must be—

4 : 5 : : 3 : 4th term = 3¾. *Ans.*

Here the proportion is inverse.

The product of the *second* and *third* terms, divided by the *first*, always gives the *fourth* term.

Of the three numbers necessary for a statement, two must contain the *supposition*, and the third the *demand*.

RULE.—Of the three given numbers, place that for the *third term* which is of the *same kind* with the *answer* sought.

Then consider, from the nature of the question, whether the answer will be greater or less than this term. If the answer is to be *greater*, place the *greater* of the two numbers for the *second term*, and the *less* number for the *first term*; but if it is to be *less*, place the *less* of the two remaining numbers for the *second term*, and the *greater* for the *first*; and, in either case, multiply the second and third terms together, and divide the

product by the first for the answer, which will always be of the same denomination as the third term.

Note.—If the first and second terms contain different denominations, they must both be reduced to the same denomination; and compound numbers to INTEGERS of the lowest denomination contained in it.

Example.—If 30 tons of hay cost $450, what will 120 tons cost.

	Tons.	Tons.	$	
Then by the Rule	30 :	120 : :	450 :	*Ans.*

$$\begin{array}{r} 120 \\ \hline 30\overline{)54000} \\ \$1800 = \textit{Ans.} \end{array}$$

INVOLUTION

Is the multiplication of any number into itself a certain number of times. The products are called Powers; the number is called the ROOT, or first power. Thus, 4 is the root, $4 \times 4 = 16$ is the square of 2d power of 4; $4 \times 4 \times 4 = 64$ is the cube of 4, or the 3d power of 4; $4 \times 4 \times 4 \times 4 = 256$ is the Biquadrate or 4th power of 4. To denote that a number is to be raised to a power, a small figure is placed above and to the right of the number whose power is to be found. It is called the *index* or *exponent*, as $4^3 = 64$, or 3d power of 4.

EVOLUTION.

Evolution (the reverse of *involution*) is the process of finding the ROOT from the power given. Thus, the *second* or *square root* of 81 is 9, because the square of 9 is 81, and the cube root of 81 is 4.326, because $4.326 \times 4.326 \times 4.326 = 81$.

The sign $\sqrt{}$ placed before a number, indicates that the square root of that number is to be found. The same symbol, with an index before it, expresses any other root.

As, $\sqrt{25} = 5$, and $4 + 6 = \sqrt{100}$.
As, $\sqrt[3]{64} = 4$, and $3 + 1 = \sqrt[3]{64}$.

TO EXTRACT THE SQUARE ROOT.

Scribner.

RULE—1st. Separate the given numbers into periods of two figures each, by placing a point over the right hand figure, and then over every second figure, counting to the left. These periods show the number of figures the *root* will consist of.

2d. Find the greatest square number in the left-hand period, and place the root of it at the right hand of the given number, after the manner of a quotient in division. Subtract the square of this root from the said period, and to the remainder bring down the next period for a new dividend.

3d. Double the quotient already found, and place it at the left of the dividend, for a *divisor*. See how many times this divisor is contained in the *new* dividend (except the right hand figure), and place the result in the root for the second figure of it, and likewise on the right hand of the *divisor*. Multiply the divisor by the *last* quotient figure, and subtract the product from the dividend, and to the remainder join the next period for a new dividend.

4th. Double the quotient already found for a *partial divisor*, and from these find the next figure in the root, as last directed, and continue the operation in the same manner until all the periods have been annexed.

5th. If these is a remainder after the last period has been found, the operation may be continued by annexing periods of ciphers.

Examples.

1. What is the length of each side of a square tract of land, containing 16 square miles? that is, what is the square root of 16? $\sqrt{16} = 4$ miles. *Ans.*

Note.—Four square miles may be represented by any four of the small squares in the annexed figure, while 4 miles square comprises the whole figure.

2. Required the square root of 42025.

```
  . . .
 42025(205
  4
405)2025
    2025
       0
```

Ramapo Wheel and Foundry Co.

For Tables of Square Roots and Cube Roots see page 267.

To Find the Square or Cube of a Higher Number than is Contained in the Table.

When the Number is Divisible by a Number Without Leaving a Remainder.

Rule—If the number exceed by 2, 3, or any other number of times, any number contained in the table, multiply the square or cube of that number in the table by the square of 2, 3, etc., and the product will give the result.

Example.—Required the square of 1800.

1800 is 10 times 180; the square of 180 is 32400; then $32400 \times 10^2 = 3240000$.

Example.—What is the cube of 2400?

2400 is 2 times 1200, and cube of 1200 is 1,728,000,000; then $1{,}728{,}000{,}000 \times 2^3 = 13{,}824{,}000{,}000$.

When the Number is an Odd Number.

Rule—Take the two numbers nearest to each other, which, added together, make that sum; then from the sum of the squares or cubes of these two numbers as per table, multiplied by 2, subtract 1, and the remainder will give the result.

Ex.—What is the square of 1745?

The nearest two numbers are $\left\{\begin{matrix}873\\872\end{matrix}\right\} = 1745$; then per table, $\left\{\begin{matrix}873^2 = 762129\\872^2 = 760384\end{matrix}\right.$

$$152.25.13 \times 2 = 3045026 - 1 = 3045025.$$

To Compute the Square Root or Cube Root of a Higher Number than is Contained in the Table.

Where the Number is Divisible by 4 or 8, Without Leaving a Remainder.

Rule—Divide the number by 4 or 8, respectively, as the square or cube root is required; take the root of the quotient in the table, multiply it by 2, and the product will give the root required.

FELLOWSHIP

Is a method of determining gains or losses of parties engaged in joint operations.

Single Fellowship.

As the whole stock is to the whole gain or loss, so is each share to the gain or loss on that share.

Two men drew a prize of $5000; A paid $2, B paid $3, for the ticket. How much is each share?

5 : 2 : : 5000 : 2000—A's share.
5 : 3 : : 5000 : 3000—B's share.

Double Fellowship,

Or, Fellowship with Time.

Rule—Multiply each share by the time of its interest in the Fellowship; then as the sum of the products is to the product of each interest, so is the whole gain or loss to each share of the gain or loss,

ALLIGATION

Is a method of finding the mean value or value rate of different materials when mixed together.

To Compute the Mean Price of the Mixture.

Rule—Multiply each quantity by its rate, divide the sum of the products by the sum of the quantities, and the quotient will be rate of the composition.

If 10 lbs. of copper, at 20 cts. per lb., 1 lb. of tin, at 5 cts., and 1 lb. of lead, at 4 cts., be mixed together, what is the value of the mixture?

```
10 × 20 = 200
 1 ×  5 =   5
 1 ×  4 =   4
---
12       )209(17.416 cents.
```

To Ascertain what Quantity of Each Article must be Taken when the Prices and Mean Price are Given.

Rule—Connect with a line each price that is *less* than the mean rate, with one or more that is *greater*. Write the difference between the mixture rate and that of each of the simples opposite the price with which it is *connected;* then the sum of the differences against any price will express the quantity to be taken of that price.

Example.—How much tea, at 72, 54, and 48 cents a pound, will compose a mixture worth 60 cents a pound.

$$60 \begin{cases} 48) \text{ ---------- } 12 \text{ at } 48 \text{ cents} \\ 54) \qquad\qquad 12 \text{ at } 54 \text{ cents.} \\ 72) 12 + 6 = 18 \text{ at } 72 \text{ cents.} \end{cases}$$

Then $12 \times 48 + 12 \times 54 + 18 \times 72 = 2520$, and $2520 \div 12 + 12 + 12 + 6 = 60$ cents.

Note.—Should it be required to mix a definite quantity of any one article, the quantities of each, determined by the above rule, must be increased or decreased in the proportion they bear to the defined quantity. Thus, had it been required to mix 18 pounds at 48 cents, the result would be 18 at 48, 18 at 54, and 27 at 72 cents per pound.

When the Whole Composition is Limited.

Rule—As the sum of the relative quantities, (as ascertained by the above rule) is to the whole quantity required, so is each quantity as ascertained to the required quantity of each.

Example.—Required 100 pounds of the above mixture.

Then $12 + 12 + 18 = 42$.

Then 42 : 100 : : 12 : 28.571.
Then 42 : 100 : : 12 : 28.571.
Then 42 : 100 : : 18 : 42.857.

Richmond Iron.

Circumferences and Areas of Circles.

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
1-32—	.0981	.00076	3¼ –	10.21	8.295	7½—	23.56	44.178
1-16	.1963	.00306		10.60	8.946		23.95	45.663
1-8 –	.3926	.01227	3½—	10.99	9 621	7¾ –	24.34	47.173
3-16	.5890	.02761		11.38	10.320		24.74	48.707
1-4—	.7854	.04908	3¾ –	11.78	11.044	8 —	25.13	50.265
5-16	.9817	.07669		12.17	11.793		25.52	51.848
3-8 –	1.178	.1104	4 —	12.56	12.566	8¼ –	25.91	53.456
7-16	1.374	.1503		12.95	13.364		26.31	55.088
1-2—	1.570	.1963	4¼ –	13.35	14.186	8½—	26.70	56.745
9-16	1.767	.2485		13.74	15.033		27.09	58.426
5-8 –	1.963	.3067	4½—	14.13	15.904	8¾ –	27.48	60.132
11-16	2.159	.3712		14.52	16.800		27.88	61.862
3-4—	2.356	.4417	4¾ –	14.92	17.720	9 —	28.27	63.617
13-16	2.552	.5184		15.31	18.665		28.66	65.396
7-8 –	2.748	.6013	5 —	15.70	19.635	9¼ –	29.05	67.200
15-16	2.945	.6902		16.10	20.629		29.45	69.029
1 —	3.141	.7854	5¼ –	16.49	21.647	9½—	29.84	70.882
	3.534	.9940		16.88	22.690		30.23	72.759
1¼ –	3.927	1.227	5½—	17.27	23.758	9¾ –	30.63	74.662
	4.319	1.484		17.67	24.850		31.02	76.588
1½—	4.712	1.767	5¾ –	18.06	25.967	10 —	31.41	78.539
	5.105	2.073		18.45	27.108		31.80	80.515
1¾ –	5.497	2.405	6 —	18.84	28.274	10¼ –	32.20	82.516
	5.890	2.761		19.24	29.464		32.59	84.540
2 —	6.283	3.141	6¼ –	19.63	30.679	10½—	32.98	86.590
	6.675	3.546		20.02	31.919		33.37	88.664
2¼ –	7.068	3.976	6½—	20.42	33.183	10¾ –	33.77	90.762
	7.461	4.430		20.81	34.471		34.16	92.885
2½—	7.854	4.908	6¾ –	21.20	35 784	11 —	34.55	95.033
	8.246	5.411		21.57	37.122		34.95	97.205
2¾ –	8.639	5.939	7 —	21.99	38.484	11¼ –	35.34	99.402
	9.032	6.491		22.38	39.871		35.73	101.62
3 —	9.424	7.068	7¼ –	22.77	41.282	11½—	36.12	103.86
	9.817	7.669		23.16	42.718		36.52	106.13

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
11¾ —	36.91	108.43	16 —	50.26	201.06	20¼ —	63.61	322.06
	37.30	110.75		50.65	204.21		64.01	326.05
12 —	37.69	113.09	16¼ —	51.05	207.39	20½ —	64.40	330.06
	38.09	115.46		51.44	210.59		64.79	334.10
12¼ —	38.48	117.85	16½ —	51.83	213.82	20¾ —	65.18	338.16
	38.87	120.27		52.22	217.07		65.58	342.25
12½ —	39.27	122.71	16¾ —	52.62	220.35	21 —	65.97	346.36
	39.66	125.18		53.01	223.65		66.36	350.49
12¾ —	40.05	127.67	17 —	53.40	226.98	21¼ —	66.75	354.65
	40.44	130.19		53.79	230.33		67.15	358.84
13 —	40.84	132.73	17¼ —	54.19	233.70	21½ —	67.54	363.05
	41.23	135.29		54.58	237.10		67.93	367.28
13¼ —	41.62	137.88	17½ —	54.97	240.52	21¾ —	68.32	371.54
	42.01	140.50		55.37	243.97		68.72	375.82
13½ —	42.41	143.13	17¾ —	55.76	247.45	22 —	69.11	380.13
	42.80	145.80		56.16	250.94		69.50	384.46
13¾ —	43.19	148.48	18 —	56.54	254.46	22¼ —	69.90	388.82
	43.58	151.20		56.94	258.01		70.29	393.20
14 —	43.98	153.93	18¼ —	57.33	261.58	22½ —	70.68	397.60
	44.37	156.69		57.72	265.18		71.07	402.03
14¼ —	44.76	159.48	18½ —	58.11	268.80	22¾ —	71.47	406.49
	45.16	162.29		58.51	272.44		71.86	410.97
14½ —	45 55	165.13	18¾ —	58.90	276.11	23 —	72.25	415.47
	45.94	167.98		59.29	279.81		72.64	420.00
14¾ —	46.33	170.87	19 —	59.69	283.52	23¼ —	73.04	424.55
	46.73	173.78		60.08	287.27		73.43	429.13
15 —	47.12	176.71	19¼ —	60.47	291.03	23½ —	73.82	433.73
	47.51	179.67		60.86	294.83		74.21	438.30
15¼ —	47.90	182.65	19½ —	61.26	298.64	23¾ —	74.61	443.01
	48.30	185.66		61.65	302.48		75.	447.69
15½ —	48.69	188.69	19¾ —	62.04	306.35	24 —	75.39	452.39
	49.08	191.74		62.43	310.24		75.79	457.11
15¾ —	49.48	194.82	20 —	62.83	314.16	24¼ —	76.18	461.86
	49.87	197.93		63.22	318.09		76.57	466.63

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam	Circ.	Area.
24½ —	76.96	471.43	28¾ –	90.32	649.18	33 —	103.6	855.30
	77.36	476.25		90.71	654.83		104.	861.79
24¾ –	77.75	481.10	29 —	91.10	660.52	33¼ –	104.4	868.30
	78.14	485.97		91.49	666.22		104.8	874.84
25 —	78.54	490.87	29¼ –	91.89	671.95	33½ —	105.2	881.41
	78.93	495.79		92.28	677.71		105.6	888.00
25¼ –	79.32	500.74	29½ —	92.67	683.49	33¾ –	106.	894.61
	79.71	505.71		93.06	689.29		106.4	901.25
25½ —	80.10	510.70	29¾ –	93.46	695.12	34 —	106.8	907.92
	80.50	515 72		93.85	700.98		107.2	914.61
25¾ –	80.89	520.70	30 —	94.24	706.86	34¼ –	107.5	921.32
	81.28	525.83		94.64	712.76		107.9	928.06
26 —	81.68	530.93	30¼ –	95.03	718.69	34½ —	108.3	934.82
	82.07	536.04		95.42	724.64		108.7	941.60
26¼ –	82.46	541.18	30½ —	95.81	730.61	34¾ –	109.1	948.41
	82.85	546.35		96.21	736.61		109.5	955.25
26½ —	83.25	551.54	30¾ –	96.60	742.64	35 —	109.9	962.11
	83.64	556.76		96.99	748.69		110.3	968.99
26¾ –	84.03	562.00	31 —	97.38	754.76	35¼ –	110.7	975.90
	84.43	567.26		97.78	760.86		111.1	982.84
27 —	84 82	572.55	31¼ –	98.17	766.99	35½ —	111.5	989.80
	85.21	577.87		98.56	773.14		111.9	996.78
27¼ –	85.60	583.20	31½ —	98.96	779.31	35¾ –	112.3	1003.7
	86.	588.57		99.35	785.51		112.7	1010.8
27½ —	86.39	593.95	31¾ –	99.74	791.73	36 —	113.	1017.8
	86.78	599.37		100.1	797.97		113.4	1024.9
27¾ –	87.17	604.80	32 —	100.5	804.24	36¼ –	113.8	1032.0
	87.57	610.26		100.9	810.54		114 2	1039.1
28 —	87.96	615.75	32¼ –	101.3	816.86	36½ —	114.6	1046.3
	88.35	621.26		101.7	823.21		115.	1053.5
28¼ –	88.75	626.79	32½ —	102.1	829.57	36¾ –	115.4	1060.7
	89.14	632.35		102.4	835.97		115.8	1067.9
28½ —	89.53	637.94	32¾ –	102.8	842.39	37 —	116.2	1075.2
	89.92	643.54		103.2	848.83		116.6	1082.4

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
37¼ –	117.	1089.7	41½ —	130.3	1352.6	45¾ –	143.7	1643.8
	117.4	1097.1		130.7	1360.8		144.1	1652.8
37½ —	117.8	1104.4	41¾ –	131.1	1369.0	46 —	144.5	1661.9
	118.2	1111.8		131.5	1377.2		144.9	1670.9
37¾ –	118.6	1119.2	42 —	131.9	1385.4	46¼ –	145 2	1680.0
	118.9	1126.6		132.3	1393.7		145.6	1689.1
38 —	119.3	1134.1	42¼ –	132.7	1401.9	46½ —	146.	1698.2
	119.7	1141.5		133.1	1410.2		146.4	1707.3
38¼ –	120.1	1149.0	42½ —	133.5	1418.6	46¾ –	146.8	1716.5
	120 5	1156.6		133.9	1426.9		147.2	1725.7
38½ —	120.9	1164.1	42¾ –	134.3	1435.3	47 —	147.6	1734.9
	121.3	1171.7		134.6	1443.7		148.	1744.1
38¾ –	121.7	1179.3	43 —	135.	1452.2	47¼ –	148.4	1753.4
	122.1	1186.9		135.4	1460.6		148.8	1762.7
39 —	122.5	1194.5	43¼ –	135.8	1469.1	47½ —	149.2	1772.0
	122.9	1202.2		136.2	1477.6		149.6	1781.3
39¼ –	123.3	1209.9	43½ —	136.6	1486.1	47¾ –	150.	1790.7
	123.7	1217.6		137.	1494.7		150.4	1800.1
39½ —	124.	1225.4	43¾ –	137.4	1503.3	48 —	150.7	1809.5
	124.4	1233.1		137.8	1511.9		150.1	1818.9
39¾ –	124.8	1240.9	44 —	138.2	1520.5	48¼ –	151.5	1828.4
	125.2	1248.7		138.6	1529.1		151.9	1837.9
40 —	125.6	1256.6	44¼ –	139.	1537.8	48½ —	152.3	1847.4
	126.	1264.5		139.4	1546.5		152.7	1856.9
40¼ –	126.4	1272.3	44½ —	139.8	1555.2	48¾ –	153.1	1866.5
	126.8	1280.3		140.1	1564.0		153.5	1876.1
40½ —	127.2	1288.2	44¾ –	140.5	1572.8	49 —	153.9	1885.7
	127.6	1296.2		140.9	1581.6		154.3	1895.3
40¾ –	128.	1304.2	45 —	141.3	1590.4	49¼ –	154.7	1905.0
	128.4	1312.2		141.7	1599.2		155.1	1914.7
41 —	128.8	1320.2	45¼ –	142.1	1608.1	49½ —	155.5	1924.4
	129.1	1328.3		142.5	1617.0		155.9	1934.1
41¼ –	129.5	1336.4	45½ —	142.9	1625.9	49¾ –	156.2	1943.9
	129.9	1344.5		143.3	1634.9		156.6	1953.6

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
50 —	157.	1963.5	54¼ —	170.4	2311.4	58½—	183.7	2687.8
	157.4	1973.3		170.8	2322.1		184.1	2699.3
50¼ —	157.8	1983.1	54½—	171.2	2332.8	58¾ —	184.5	2710.8
	158.2	1993.0		171.6	2343.5		184.9	2722.4
50½—	158.6	2002.9	54¾ —	172.	2354.2	59 —	185.3	2733.9
	159.	2012.8		172.3	2365.0		185.7	2745.5
50¾ —	159 4	2022.8	55 —	172.7	2375.8	59¼ —	186.1	2757.1
	159.8	2032.8		173.1	2386.6		186.5	2768.8
51 —	160.2	2042.8	55¼ —	173.5	2397.4	59½—	186.9	2780.5
	160.6	2052.8		173.9	2408.3		187.3	2792.2
51¼ —	161.	2062.9	55½—	174.3	2419.2	59¾ —	187 7	2803.9
	161.3	2072.9		174.7	2430.1		188.1	2815.6
51½—	161.7	2083.0	55¾ —	175.1	2441.0	60 —	188.4	2827.4
	162.1	2093.2		175.5	2452.0		188.8	2839.2
51¾ —	162.5	2103.3	56 —	175.9	2463.0	60¼ —	189.2	2851.0
	162.9	2113.5		176.3	2474.0		189.6	2862.8
52 —	163.3	2123.7	56¼ —	176.7	2485.0	60½—	190.	2874.7
	163.7	2133.9		177.1	2496.1		190.4	2886.6
52¼ —	164.1	2144.1	56½—	177.5	2507.1	60¾ —	190.8	2898.5
	164.5	2154.4		177.8	2518.2		191.2	2910.5
52½—	164.9	2164.7	56¾ —	178.2	2529.4	61 —	191.6	2922.4
	165.3	2175.0		178.6	2540.5		192.	2934.4
52¾ —	165.7	2185.4	57 —	179.	2551.7	61¼ —	192.4	2946.4
	166.1	2195.7		179.4	2562.9		192.8	2958.5
53 —	166.5	2206.1	57¼ —	179.8	2574.1	61½—	193.2	2970.5
	166.8	2216.6		180.2	2585.4		193.6	2982.6
53¼ —	167.2	2227.0	57½—	180.6	2596.7	61¾ —	193.9	2994.7
	167.6	2237.5		181.	2608.0		194.3	3006.9
53½—	168.	2248.0	57¾ —	181.4	2619.3	62 —	194.7	3019.0
	168.4	2258.5		181.8	2630.7		195.1	3031.2
53¾ —	168 8	2269.0	58 —	182.2	2642.0	62¼ —	195.5	3043.4
	169.2	2279.6		182.6	2653.4		195.9	3055.7
54 —	169.6	2290.2	58¼ —	182.9	2664.9	62½—	196.3	3067.9
	170.	2300.8		183.3	2676.3		196.7	3080.2

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
62¾ —	197.1	3092.5	67 —	210.4	3525.6	71¼ —	223.8	3987.1
	197.5	3104.8		210.8	3538.8		224.2	4001.1
63 —	197.9	3117.2	67¼ —	211.2	3552.0	71½ —	224.6	4015.1
	198.3	3129.6		211.6	3565.2		225.	4029.2
63¼ —	198.7	3142.0	67½ —	212.	3578.4	71¾ —	225.4	4043.2
	199.	3154.4		212.4	3591.7		225.8	4067.3
63½ —	199.4	3166.9	67¾ —	212.8	3605.0	72 —	226.1	4071.5
	199.8	3179.4		213.2	3618.3		226.5	4085.6
63¾ —	200.2	3191.9	68 —	213.6	3631.6	72¼ —	226.9	4099.8
	200.6	3204.4		214.	3645.0		227.3	4114.0
64 —	201.	3216.9	68¼ —	214.4	3658.4	72½ —	227.7	4128.2
	201.4	3229.5		214.8	3671.8		228.1	4142.5
64¼ —	201.8	3242.1	68½ —	215.1	3685.2	72¾ —	228.5	4156.7
	202.2	3254.8		215.5	3698.7		228.9	4171.0
64½ —	202.6	3267.4	68¾ —	215.9	3712.2	73 —	229.3	4185.3
	203.	3280.1		216.3	3725.7		229.7	4199.7
64¾ —	203.4	3292.8	69 —	216.7	3739.2	73¼ —	230.1	4214.1
	203.8	3205.5		217.1	3752.8		230.5	4228.5
65 —	204.2	3318.3	69¼ —	217.5	3766.4	73½ —	230.9	4242.9
	204.5	3331.0		217.9	3780.0		231.3	4257.3
65¼ —	204.9	3343.8	69½ —	218.3	3793.6	73¾ —	231.6	4271.8
	205.3	3356.7		218.7	3807.3		232.	4286.3
65½ —	205.7	3369.5	69¾ —	219.1	3821.0	74 —	232.4	4300.8
	206.1	3382.4		219.5	3834.7		232.8	4315.3
65¾ —	206.5	3395.3	70 —	219.9	3848.4	74¼ —	233.2	4329.9
	206.9	3408.2		220.3	3862.2		233.6	4344.5
66 —	207.3	3421.2	70¼ —	220.6	3875.9	74½ —	234.	4359.1
	207.7	3434.1		221.	3889.8		234.4	4373.8
66¼ —	208.1	3447.1	70½ —	221.4	3903.6	74¾ —	234.8	4388.4
	208.5	3460.1		221.8	3917.4		235.2	4403.1
66½ —	208.9	3473.2	70¾ —	222.2	3931.3	75 —	235.6	4417.8
	209.3	3486.3		222.6	3945.2		236.	4432.6
66¾ —	209.7	3499.3	71 —	223.	3959.2	75¼ —	236.4	4447.3
	210.	3512.5		223.4	3973.1		236.7	4462.1

CIRCUMFERENCES AND AREAS OF CIRCLES—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
75¼ —	237.1	4476.9	79¾ —	250.5	4995.1	84 —	263.8	5541.7
	237.5	4491.8		250.9	5010.8		264.2	5558.2
75¾ —	237.9	4506.6	80 —	251.3	5026.5	84¼ —	264.6	5574.8
	238.3	4521.5		251.7	5042.2		265.	5591.3
76 —	238.7	4536.4	80¼ —	252.1	5058.0	84½ —	265.4	5607.9
	239.1	4551.4		252.5	5073.7		265.8	5624.5
76¼ —	239.5	4566.3	80½ —	252.8	5089.5	84¾ —	266.2	5641.1
	239.9	4581.3		253.2	5105.4		266.6	5657.8
76½ —	240.3	4596.3	80¾ —	253.6	5121.2	85 —	267.	5674.5
	240.7	4611.3		254.	5137.1		267.4	5691.2
76¾ —	241.1	4626.4	81 —	254.4	5153.0	85¼ —	267.8	5707.9
	241.5	4641.5		254.8	5168.9		268.2	5724.6
77 —	241.9	4656.6	81¼ —	255.2	5184.8	85½ —	269.6	5741.4
	242.2	4671.7		255.6	5200.8		268.9	5758.2
77¼ —	242.6	4686.9	81½ —	256.	5216.8	85¾ —	269.3	5775.0
	243.	4702.1		256.4	5232.8		269.7	5791.9
77½ —	243.4	4717.3	81¾ —	256.8	5248.8	86 —	270.1	5808.8
	243.8	4732.5		257.2	5264.9		270.5	5825.7
77¾ —	244.2	4747.7	82 —	257.6	5281.0	86¼ —	270.9	5842.6
	244.6	4763.0		258.	5297.1		271.3	5859.5
78 —	245.	4778.3	82¼ —	258.3	5313.2	86½ —	271.7	5876.5
	245.4	4793.7		258.7	5329.4		272.1	5893.5
78¼ —	245.8	4809.0	82½ —	259.1	5345.6	86¾ —	272.5	5910.5
	246.2	4824.4		259.5	5361.8		272.9	5927.6
78½ —	246.6	4839.8	82¾ —	259.9	5378.0	87 —	273.3	5944.6
	247.	4855.2		260.3	5394.3		273.7	5961.7
78¾ —	247.4	4870.7	83 —	260.7	5410.6	87¼ —	274.1	5978.9
	247.7	4886.1		261.1	5426.9		274.4	5996.0
79 —	248.1	4901.6	83¼ —	261.5	5443.2	87½ —	274.8	6013.2
	248.5	4917.2		261.9	5459.6		275.2	6030.4
79¼ —	248.9	4932.7	83½ —	262.3	5476.0	87¾ —	275.6	6047.6
	249.3	4948.3		262.7	5492.4		276.	6064.8
79½ —	249.7	4963.9	83¾ —	263.1	5508.8	88 —	276.4	6082.1
	250.1	4979.5		263.5	5525.3		276.8	6099.4

Circumferences and Areas of Circles—*Continued.*

Diam.	Circ.	Area.	Diam.	Circ.	Area.	Diam.	Circ.	Area.
88¼ —	277.2	6116.7	92½ —	290.5	6720.0	96¾ —	303.9	7351.7
	277.6	6134.0		290.9	6738.2		304.3	7370.7
88½ —	278.	6151.4	92¾ —	291.3	6756.4	97 —	304.7	7389.8
	278.4	6168.8		291.7	6776.4		305.1	7408.8
88¾ —	278.8	6186.2	93 —	292.1	6792.9	97¼ —	305.5	7427.9
	279.2	6203.6		292.5	6811.1		305.9	7447.0
89 —	279.6	6221.1	93¼ —	292.9	6829.4	97½ —	306.3	7466.2
	279.9	6238.6		293.3	6847.8		306.6	7485.3
89¼ —	280.3	6256.1	93½ —	293.7	6866.1	97¾ —	307.	7504.5
	280.7	6273.6		294.1	6884.5		307.4	7523.7
89½ —	281.1	6291.2	93¾ —	294.5	6902.9	98 —	307.8	7542.9
	281.5	6308.8		294.9	6921.3		308.2	7562.2
89¾ —	281.9	6326.4	94 —	295.3	6939.7	98¼ —	308.6	7581.5
	282.3	6344.0		295.7	6958.2		309.0	7600.8
90 —	282.7	6361.7	94¼ —	296.	6976.7	98½ —	309.4	7620.1
	283.1	6379.4		296.4	6995.2		309.8	7639.4
90¼ —	283.5	6397.1	94½ —	296.8	7013.8	98¾ —	310.2	7658.8
	283.9	6414.8		297.2	7032.3		310.6	7678.2
90½ —	284.3	6432.6	94¾ —	297.6	7050.9	99 —	311.0	7697.7
	284.7	6450.4		298.	7069.5		311.4	7717.1
90¾ —	285.1	6468.2	95 —	298.4	7088.2	99¼ —	311.8	7736.6
	285.4	6486.0		298.8	7106.9		312.1	7756.1
91 —	285.8	6503.8	95¼ —	299.2	7125.5	99½ —	312.5	7775.6
	286.2	6521.7		299.6	7144.3		312.9	7795.2
91¼ —	286.6	6539.6	95½ —	300.	7163.0	99¾ —	313.3	7814.7
	287.	6557.6		300.4	7181.8		313.7	7834.3
91½ —	287.4	6575.5	95¾ —	300.8	7200.5	100 —	314.1	7853.6
	287.8	6593.5		301.2	7219.4		314.5	7853.9
91¾ —	288.2	6611.5	96 —	301.5	7238.2	100¼ —	314.9	7893.3
	288.6	6629.5		301.9	7257.1		315.3	7913.1
92 —	289.	6647.6	96¼ —	302.3	7275.9	100½ —	315.7	7932.7
	289.4	6665.7		302.7	7294.9		316.0	7942.4
92¼	289.8	6683.8	96½ —	303.1	7313.8	100¾ —	316.4	7972.2
	290.2	6701.9		303.5	7332.8		316.8	7991.9

Squares, Cubes, Square Roots, and Cube Roots.

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
1	1	1	1.0	1.0	31	961	29791	5.567	3.141
2	4	8	1.414	1.259	32	1024	32768	5.656	3.174
3	9	27	1.732	1.442	33	1089	35937	5.744	3.207
4	16	64	2.0	1.587	34	1156	39304	5.830	3.239
5	25	125	2.230	1.709	35	1225	42875	5.916	3.271
6	36	216	2.449	1.817	36	1296	46656	6.0	3.301
7	49	343	2.645	1.912	37	1369	50653	6.082	3.332
8	64	512	2.828	2.0	38	1444	54872	6.164	3.361
9	81	729	3.0	2.080	39	1521	59319	6.245	3.391
10	100	1000	3.162	2.154	40	1600	64000	6.324	3.419
11	121	1331	3.316	2.223	41	1681	68921	6.403	3.448
12	144	1728	3.464	2.289	42	1764	74088	6.480	3.476
13	169	2197	3.605	2.351	43	1849	79507	6.557	3.503
14	196	2744	3.741	2.410	44	1936	85184	6.633	3.530
15	225	3375	3.872	2.466	45	2025	91125	6.708	3.556
16	256	4096	4.0	2.519	46	2116	97336	6.782	3.583
17	289	4913	4.123	2.571	47	2209	103823	6.855	3.608
18	324	5832	4.242	2.620	48	2304	110592	6.928	3.634
19	361	6859	4.358	2.668	49	2401	117649	7.0	3.659
20	400	8000	4.472	2.714	50	2500	125000	7.071	3.684
21	441	9261	4.582	2.758	51	2601	132651	7.141	3.708
22	484	10648	4.690	2.802	52	2704	140608	7.211	3.732
23	529	12167	4.795	2.843	53	2809	148877	7.280	3.756
24	576	13824	4.898	2.884	54	2916	157464	7.348	3.779
25	625	15625	5.0	2.924	55	3025	166375	7.416	3.802
26	676	17576	5.099	2.962	56	3136	175616	7.483	3.825
27	729	19683	5.196	3.0	57	3249	185193	7.549	3.848
28	784	21952	5.291	3.036	58	3364	195112	7.615	3.870
29	841	24389	5.385	3.072	59	3481	205379	7.681	3.893
30	900	27000	5.477	3.107	60	3600	216000	7.745	3.914

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
61	3721	226981	7.810	3.936	91	8281	753571	9.539	4.497
62	3844	238328	7.874	3.957	92	8464	778688	9.591	4.514
63	3969	250047	7.937	3.979	93	8649	804357	9.643	4.530
64	4096	262144	8.0	4.0	94	8836	830584	9.695	4.546
65	4225	274625	8.062	4.020	95	9025	857375	9.746	4.562
66	4356	287496	8.124	4.041	96	9216	884736	9.797	4.578
67	4489	300763	8.185	4.061	97	9409	912673	9.848	4.594
68	4624	314432	8.246	4.081	98	9604	941192	9.899	4.610
69	4761	328509	8.306	4.101	99	9801	970299	9.949	4.626
70	4900	343000	8.366	4.121	100	10000	1000000	10.0	4.641
71	5041	357911	8.426	4.140	101	10201	1030301	10.049	4.657
72	5184	373248	8.485	4.160	102	10404	1061208	10.099	4.672
73	5329	389017	8.544	4.179	103	10609	1092727	10.148	4.687
74	5476	405224	8.602	4.198	104	10816	1124864	10.198	4.702
75	5625	421875	8.660	4.217	105	11025	1157625	10.246	4.717
76	5776	438976	8.717	4.235	106	11236	1191016	10.295	4.732
77	5929	456533	8.774	4.254	107	11449	1225043	10.344	4.747
78	6084	474552	8.831	4.272	108	11664	1259712	10.392	4.762
79	6241	493039	8.888	4.290	109	11881	1295029	10.440	4.776
80	6400	512000	8.944	4.308	110	12100	1331000	10.488	4.791
81	6561	531441	9.0	4.326	111	12321	1367631	10.535	4.805
82	6724	551368	9.055	4.344	112	12544	1404928	10.583	4.820
83	6889	571787	9.110	4.362	113	12769	1442897	10.630	4.834
84	7056	592704	9.165	4.379	114	12996	1481544	10.677	4.848
85	7225	614125	9.219	4.396	115	13225	1520875	10.723	4.862
86	7396	636056	9.273	4.414	116	13456	1560896	10.770	4.877
87	7569	658503	9.327	4.431	117	13689	1601613	10.816	4.890
88	7744	681472	9.380	4.447	118	13924	1643032	10.862	4.904
89	7921	704969	9.433	4.464	119	14161	1685159	10.908	4.918
90	8100	729000	9.486	4.481	120	14400	1728000	10.954	4.932

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
121	14641	1771561	11.0	4.946	151	22801	3442951	12.288	5.325
122	14884	1815848	11.045	4.959	152	23104	3511008	12.328	5.336
123	15129	1860867	11.090	4.973	153	23409	3581577	12.369	5.348
124	15376	1906624	11.135	4.986	154	23716	3652264	12.409	5.360
125	15625	1953125	11.180	5.0	155	24025	3723875	12.449	5.371
126	15876	2000376	11.224	5.013	156	24336	3796416	12.490	5.383
127	16129	2048383	11.269	5.026	157	24649	3869893	12.529	5.394
128	16384	2097152	11.313	5.039	158	24964	3944312	12.569	5.406
129	16641	2146689	11.357	5.052	159	25281	4019679	12.609	5.417
130	16900	2197000	11.401	5.065	160	25600	4096000	12.649	5.428
131	17161	2248091	11.445	5.078	161	25921	4173281	12.688	5.440
132	17424	2299968	11.489	5.091	162	26244	4251528	12.727	5.451
133	17689	2352637	11.532	5.104	163	26569	4330747	12.767	5.462
134	17956	2406104	11.575	5.117	164	26896	4410944	12.806	5.473
135	18225	2460375	11.618	5.129	165	27225	4492125	12.845	5.484
136	18496	2515456	11.661	5.142	166	27556	4574296	12.884	5.495
137	18769	2571353	11.704	5.155	167	27889	4657463	12.922	5.506
138	19044	2628072	11.747	5.167	168	28224	4741632	12.961	5.517
139	19321	2685619	11.789	5.180	169	28561	4826809	13.0	5.528
140	19600	2744000	11.832	5.192	170	28900	4913000	13.038	5.539
141	19881	2803221	11.874	5.204	171	29241	5000211	13.076	5.550
142	20164	2863288	11.916	5.217	172	29584	5088448	13.114	5.561
143	20449	2924207	11.958	5.229	173	29929	5177717	13.152	5.572
144	20736	2985984	12.0	5.241	174	30276	5268024	13.190	5.582
145	21025	3048625	12.041	5.253	175	30625	5359375	13.228	5.593
146	21316	3112136	12.083	5.265	176	30976	5451776	13.266	5.604
147	21609	3176523	12.124	5.277	177	31329	5545233	13.304	5.614
148	21904	3241792	12.165	5.289	178	31684	5639752	13.341	5.625
149	22201	3307949	12.206	5.301	179	32041	5735339	13.379	5.635
150	22500	3375000	12.247	5.313	180	32400	5832000	13.416	5.646

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
181	32761	5929741	13.453	5.656	211	44521	9393931	14.525	5.953
182	33124	6028568	13.490	5.667	212	44944	9528128	14.560	5.962
183	33489	6128487	13.527	5.677	213	45369	9663597	14.594	5.972
184	33856	6229504	13.564	5.687	214	45796	9800344	14.628	5.981
185	34225	6331625	13.601	5.698	215	46225	9938375	14.662	5.990
186	34596	6434856	13.638	5.708	216	46656	10077696	14.696	6.0
187	34969	6539203	13.674	5.718	217	47089	10218313	14.730	6.009
188	35344	6644672	13.711	5.728	218	47524	10360232	14.764	6.018
189	35721	6751269	13.747	5.738	219	47961	10503459	14.798	6.027
190	36100	6859000	13.784	5.748	220	48400	10648000	14.832	6.036
191	36481	6967871	13.820	5.758	221	48841	10793861	14.866	6.045
192	36864	7077888	13.856	5.769	222	49284	10941048	14.899	6.055
193	37249	7189517	13.892	5.779	223	49729	11089567	14.933	6.064
194	37636	7301384	13.928	5.788	224	50176	11239424	14.966	6.073
195	38025	7414875	13.964	5.798	225	50625	11390625	15.0	6.082
196	38416	7529536	14.0	5.808	226	51076	11543176	15.033	6.099
197	38809	7645373	14.035	5.818	227	51529	11697083	15.066	6.100
198	39204	7762392	14.071	5.828	228	51984	11852352	15.099	6.109
199	39601	7880599	14.106	5.838	229	52441	12008989	15.132	6.118
200	40000	8000000	14.142	5.848	230	52900	12167000	15.165	6.126
201	40401	8120601	14.177	5.857	231	53361	12326391	15.198	6.135
202	40804	8242408	14.212	5.867	232	53824	12487168	15.231	6.144
203	41209	8365427	14.247	5.877	233	54289	12649337	15.264	6.153
204	41616	8489664	14.282	5.886	234	54756	12812904	15.297	6.162
205	42025	8615125	14.317	5.896	235	55225	12977875	15.329	6.171
206	42436	8741816	14.352	5.905	236	55696	13144256	15.362	6.179
207	42849	8869743	14.387	5.915	237	56169	13312053	15.394	6.188
208	43264	8998912	14.422	5.924	238	56644	13481272	15.427	6.197
209	43681	9129329	14.456	5.934	239	57121	13651919	15.459	6.205
210	44100	9261000	14.491	5.943	240	57600	13824000	15.491	6.214

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
241	58081	13997521	15.524	6.233	271	73441	19902511	16 462	6.471
242	58564	14172488	15.556	6.231	272	73984	20123648	16.492	6.479
243	59049	14348907	15.588	6.240	273	74529	20346417	16.522	6.487
244	59536	14526784	15.620	6.248	274	75076	20570824	16.552	6.495
245	60025	14706125	15.652	6.257	275	75625	20796875	16.583	6.502
246	60516	14886936	15.684	6.265	276	76176	21024576	16.613	6.510
247	61009	15069223	15.716	6.274	277	76729	21253933	16.643	6.518
248	61504	15252992	15.748	6.282	278	77284	21484952	16.678	6.526
249	62001	15438249	15.779	6.291	279	77841	21717639	16.703	6.534
250	62500	15625000	15.811	6.299	280	78400	21952000	16.733	6.542
251	63001	15813251	15.842	6.307	281	78961	22188041	16.763	6.549
252	63504	16003008	15.874	6.316	282	79524	22425768	16.792	6.557
253	64009	16194277	15.905	6.324	283	80089	22665187	16.822	6.565
254	64516	16387064	15.937	6.333	284	80656	22906304	16.852	6.573
255	65025	16581375	15.968	6.341	285	81225	23149125	16.881	6.580
256	65536	16777216	16.0	6.349	286	81796	23393656	16.911	6.588
257	66049	16974593	16.031	6.357	287	82369	23639903	16.941	6.596
258	66564	17173512	16.062	6.366	288	82944	23887872	16.970	6.603
259	67081	17373979	16.093	6.374	289	83521	24137569	17.0	6.611
260	67600	17576000	16.124	6.382	290	84100	24389000	17.029	6.619
261	68121	17779581	16.155	6.390	291	84681	24642171	17.058	6.626
262	68644	17984728	16.186	6.398	292	85264	24897088	17.088	6.634
263	69169	18191447	16.217	6.406	293	85849	25153757	17 117	6.641
264	69696	18399744	16.248	6.415	294	86436	25412184	17.146	6.649
265	70225	18609625	16.278	6.423	295	87025	25672375	17.175	6.656
266	70756	18821096	16.309	6.431	296	87616	25934836	17.204	6.664
267	71289	19034163	16.340	6.439	297	88209	26198073	17.233	6.671
268	71824	19248832	16.370	6.447	298	88804	26463592	17.262	6.678
269	72361	19465109	16.401	6.455	299	89401	26730899	17.291	6.686
270	72900	19683000	16.431	6.463	300	90000	27000000	17.320	6.694

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
301	90601	27270901	17.349	6.701	331	109561	36264691	18.193	6.917
302	91204	27543608	17.378	6.709	332	110224	36594368	18.220	6.924
303	91809	27818127	17.406	6.716	333	110889	36926037	18.248	6.931
304	92416	28094464	17.435	6.723	334	111556	37259704	18.275	6.938
305	93025	28372625	17.464	6.731	335	112225	37595375	18.303	6.945
306	93636	28652616	17.492	6.738	336	112896	37933056	18.330	6.952
307	94249	28934443	17.521	6.745	337	113569	38272753	18.357	6.958
308	94864	29218112	17.549	6.753	338	114244	38614472	18.384	6.965
309	95481	29503609	17.578	6.760	339	114921	38958219	18.411	6.972
310	96100	29791000	17.606	6.767	340	115600	39304000	18.439	6.979
311	96721	30080231	17.635	6.775	341	116281	39651821	18.466	6.986
312	97344	30371328	17.663	6.782	342	116964	40001688	18.493	6.993
313	97969	30664297	17.691	6.789	343	117649	40353607	18.520	7.0
314	98596	30959144	17.720	6.796	344	118336	40707584	18.547	7.006
315	99225	31255875	17.748	6.804	345	119025	41063625	18.574	7.013
316	99856	31554496	17.776	6.811	346	119716	41421736	18.601	7.020
317	100489	31855013	17.804	6.818	347	120409	41781923	18.627	7.027
318	101124	32157432	17.832	6.825	348	121104	42144192	18.654	7.033
319	101761	32461759	17.860	6.832	349	121801	42508549	18.681	7.040
320	102400	32768000	17.888	6.839	350	122500	42875000	18.708	7.047
321	103041	33076161	17.916	6.847	351	123201	43243551	18.734	7.054
322	103684	33386248	17.944	6.854	352	123904	43614208	18.761	7.060
323	104329	33698267	17.972	6.861	353	124609	43986977	18.788	7.067
324	104976	34012224	18.0	6.868	354	125316	44361864	18.814	7.074
325	105625	34328125	18.027	6.875	355	126025	44738875	18.841	7.080
326	106276	34645976	18.055	6.882	356	126736	45118016	18.867	7.087
327	106929	34965783	18.083	6.889	357	127449	45499293	18.894	7.093
328	107584	35287552	18.110	6.896	358	128164	45882712	18.920	7.100
329	108241	35611289	18.138	6.903	359	128881	46268279	18.947	7.107
330	108900	35937000	18.165	6.910	360	129600	46656000	18.973	7.113

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
361	130321	47045881	19.0	7.120	391	152881	59776471	19.773	7.312
362	131044	47437928	19.026	7.126	392	153664	60236288	19.798	7.318
363	131769	47832147	19.052	7.133	393	154449	60698457	19.824	7.324
364	132496	48228544	19.078	7.140	394	155236	61162984	19.849	7.331
365	133225	48627125	19.104	7.146	395	156025	61629875	19.874	7.337
366	133956	49027896	19.131	7.153	396	156816	62099136	19.899	7.343
367	134689	49430863	19.157	7.159	397	157609	62570773	19.924	7.349
368	135424	49836032	19.183	7.166	398	158404	63044792	19.949	7.355
369	136161	50243409	19.209	7.172	399	159201	63521199	19.974	7.361
370	136900	50653000	19.235	7.179	400	160000	64000000	20.0	7.368
371	137641	51064811	19.261	7.185	401	160801	64481201	20.024	7.374
372	138384	51478848	19.287	7.191	402	161604	64964808	20.049	7.380
373	139129	51895117	19.313	7.198	403	162409	65450827	20.074	7.386
374	139876	52313624	19.339	7.204	404	163216	65939264	20.099	7.392
375	140625	52734375	19.364	7.211	405	164025	66430125	20.124	7.398
376	141376	53157376	19.390	7.217	406	164836	66923416	20.149	7.404
377	142129	53582633	19.416	7.224	407	165649	67419143	20.174	7.410
378	142884	54010152	19.442	7.230	408	166464	67917312	20.199	7.416
379	143641	54439939	19.467	7.236	409	167281	68417929	20.223	7.422
380	144400	54872000	19.493	7.243	410	168100	68921000	20.248	7.428
381	145161	55306341	19.519	7.249	411	168921	69426531	20.273	7.434
382	145924	55742968	19.544	7.255	412	169744	69934528	20.297	7.441
383	146689	56181887	19.570	7.262	413	170569	70444997	20.322	7.447
384	147456	56623104	19.595	7.268	414	171396	70957944	20.346	7.453
385	148225	57066625	19.621	7.274	415	172225	71473375	20.371	7.459
386	148996	57512456	19.646	7.281	416	173056	71991296	20.396	7.465
387	149769	57960603	19.672	7.287	417	173889	72511713	20.420	7.471
388	150544	58411072	19.697	7.293	418	174724	73034632	20.445	7.476
389	151321	58863869	19.723	7.299	419	175561	73560059	20.469	7.482
390	152100	59319000	19.748	7.306	420	176400	74088000	20.493	7.488

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
421	177241	74618461	20.518	7.494	451	203401	91733851	21 236	7.668
422	178084	75151448	20.542	7.500	452	204304	92345408	21.260	7.674
423	178929	75686967	20.566	7 506	453	205209	92959677	21.283	7.680
424	179776	76225024	20.591	7.512	454	206116	93576664	21.307	7.685
425	180625	76765625	20.615	7.518	455	207025	94196375	21.330	7.691
426	181476	77308776	20.639	7.524	456	207936	94818816	21.354	7.697
427	182329	77854483	20.663	7.530	457	208849	95443993	21.377	7.702
428	183184	78402752	20.688	7.536	458	209764	96071912	21 400	7.708
429	184041	78953589	20.712	7.541	459	210681	96702579	21.424	7.713
430	184900	79507000	20 736	7.547	460	211600	97336000	21.447	7.719
431	185761	80062991	20.760	7.553	461	212521	97972181	21.470	7.725
432	186624	80621568	20.784	7.559	462	213444	98611128	21.494	7.730
433	187489	81182737	20.808	7.565	463	214369	99252847	21.517	7.736
434	188356	81746504	20 832	7.571	464	215296	99897344	21.540	7.741
435	189225	82312875	20.856	7.576	465	216225	100544625	21.563	7.747
436	190096	82881856	20.880	7.582	466	217156	101194696	21 587	7.752
437	190969	83453453	20.904	7.588	467	218089	101847563	21.610	7.758
438	191844	84027672	20.928	7.594	468	219024	102503232	21.633	7.763
439	192721	84604519	20.952	7.600	469	219961	103161709	21.656	7.769
440	193600	85184000	20.976	7.605	470	220900	103823000	21.679	7.774
441	194481	85766121	21.0	7.611	471	221841	104487111	21.702	7.780
442	195364	86350888	21.023	7.617	472	222784	105154048	21.725	7.785
443	196249	86938307	21.047	7.623	473	223729	105828817	21.748	7.791
444	197136	87528384	21.071	7.628	474	224676	106496424	21.771	7.796
445	198025	88121125	21.095	7.634	475	225625	107171875	21.794	7.802
446	198916	88716536	21.118	7.640	476	226576	107850176	21.817	7.807
447	199809	89314623	21.142	7.646	477	227529	108531333	21.840	7.813
448	200704	89915392	21.166	7.651	478	228484	109215352	21.863	7.818
449	201601	90518849	21.189	7.657	479	229441	109902239	21.886	7.824
450	202500	91125000	21.213	7.663	480	230400	110592000	21.908	7.829

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
481	231361	111284641	21.931	7.835	511	261121	133432831	22.605	7.994
482	232324	111980168	21.954	7.840	512	262144	134217728	22.627	8.0
483	233289	112678587	21.977	7.846	513	263169	135005697	22.649	8.005
484	234256	113379904	22.0	7.851	514	264196	135796744	22.671	8.010
485	235225	114084125	22.022	7.856	515	265225	136590875	22.693	8.015
486	236196	114791256	22.045	7.862	516	266256	137388096	22.715	8.020
487	237169	115501303	22.068	7.867	517	267289	138188413	22.737	8.025
488	238144	116214272	22.090	7.872	518	268324	138991832	22.759	8.031
489	239121	116930169	22.113	7.878	519	269361	139798359	22.781	8.036
490	240100	117649000	22.135	7.883	520	270400	140608000	22.803	8.041
491	241081	118370771	22.158	7.889	521	271441	141420761	22.825	8.046
492	242064	119095488	22.181	7.894	522	272484	142236648	22.847	8.051
493	243049	119823157	22.203	7.899	523	273529	143055667	22.869	8.056
494	244036	120553784	22.226	7.905	524	274576	143877824	22.891	8.062
495	245025	121287375	22.248	7.910	525	275625	144703125	22.912	8.067
496	246016	122023936	22.271	7.915	526	276676	145531576	22.934	8.072
497	247009	122763473	22.293	7.921	527	277729	146363183	22.956	8.077
498	248004	123505992	22.315	7.926	528	278784	147197952	22.978	8.082
499	249001	124251499	22.338	7.931	529	279841	148035889	23.0	8.087
500	250000	125000000	22.360	7.937	530	280900	148877000	23.021	8.092
501	251001	125751501	22.383	7.942	531	281961	149721291	23.043	8.097
502	252004	126506008	22.405	7.947	532	283024	150568768	23.065	8.102
503	253009	127263527	22.427	7.952	533	284089	151419437	23.086	8.107
504	254016	128024064	22.449	7.958	534	285156	152273304	23.108	8.112
505	255025	128787625	22.472	7.963	535	286225	153130375	23.130	8.118
506	256036	129554216	22.494	7.968	536	287296	153990656	23.151	8.128
507	257049	130323843	22.516	7.973	537	288369	154854153	23.173	8.128
508	258064	131096512	22.538	7.979	538	289444	155720872	23.194	8.133
509	259081	131872229	22.561	7.984	539	290521	156590819	23.216	8.138
510	260100	132651000	22.583	7.989	540	291600	157464000	23.237	8.143

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
541	292681	158340421	23.259	8.148	571	326041	186169411	23.895	8.296
542	293764	159220088	23.280	8.153	572	327184	187149248	23.916	8.301
543	294849	160103007	23.302	8.158	573	328329	188132517	23.937	8.305
544	295936	160989184	23.323	8.163	574	329476	189119224	23.958	8.310
545	297025	161878625	23.345	8.168	575	330625	190109375	23.979	8.315
546	298116	162771336	23.366	8.173	576	331776	191102976	24.0	8.320
547	299209	163667323	23.388	8.178	577	332929	192100033	24.020	8.325
548	300304	164566592	23.409	8.183	578	334084	193100552	24.041	8.329
549	301401	165469149	23.430	8.188	579	335241	194104539	24.062	8.334
550	302500	166375000	23.452	8.193	580	336400	195112000	24.083	8.339
551	303601	167284151	23.473	8.198	581	337561	196122941	24.103	8.344
552	304704	168196608	23.494	8.203	582	338724	197137368	24.124	8.349
553	305809	169112377	23.515	8.208	583	339889	198155287	24.145	8.353
554	306916	170031464	23.537	8.213	584	341056	199176704	24.166	8.358
555	308025	170953875	23.558	8.217	585	342225	200201625	24.186	8.363
556	309136	171879616	23.579	8.222	586	343396	201230056	24.207	8.368
557	310249	172808693	23.600	8.227	587	344569	202262003	24.228	8.372
558	311364	173741112	23.622	8.232	588	345744	203297472	24.248	8.377
559	312481	174676879	23.643	8.237	589	346921	204336469	24.269	8.382
560	313600	175616000	23.664	8.242	590	348100	205379000	24.289	8.387
561	314721	176558481	23.685	8.247	591	349281	206425071	24.310	8.391
562	315844	177504328	23.706	8.252	592	350464	207474688	24.331	8.396
563	316969	178453547	23.727	8.257	593	351649	208527857	24.351	8.401
564	318096	179406144	23.748	8.262	594	352836	209584584	24.372	8.406
565	319225	180362125	23.769	8.267	595	354025	210644875	24.392	8.410
566	320356	181321496	23.790	8.271	596	355216	211708736	24.413	8.415
567	321489	182284263	23.811	8.276	597	356409	212776173	24.433	8.420
568	322624	183250432	23.832	8.281	598	357604	213847192	24.454	8.424
569	323761	184220009	23.853	8.286	599	358801	214921799	24.474	8.429
570	324900	185193000	23.874	8.291	600	360000	216000000	24.494	8.434

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
601	361201	217081801	24.515	8.439	631	398161	251239591	25.119	8.577
602	362404	218167208	24.535	8.443	632	399424	252435968	25.139	8.581
603	363609	219256227	24.556	8.448	633	400689	253636137	25.159	8.586
604	364816	220348864	24.576	8.453	634	401956	254840104	25.179	8.590
605	366025	221445125	24.596	8.457	635	403225	256047875	25.199	8.595
606	367236	222545016	24.617	8.462	636	404496	257259456	25.219	8.599
607	368449	223648543	24.637	8.467	637	405769	258474853	25.238	8.604
608	369664	224755712	24.657	8.471	638	407044	259694072	25.258	8.608
609	370881	225866529	24.677	8.476	639	408321	260917119	25.278	8.613
610	372100	226981000	24.698	8.480	640	409600	262144000	25.298	8.617
611	373321	228099131	24.718	8.485	641	410881	263374721	25.317	8.622
612	374544	229220928	24.738	8.490	642	412164	264609288	25.337	8.626
613	375769	230346397	24.758	8.494	643	413449	265847707	25.357	8.631
614	376996	231475544	24.779	8.499	644	414736	267089984	25.377	8.635
615	378225	232608375	24.799	8.504	645	416025	268336125	25.396	8.640
616	379456	233744896	24.819	8.508	646	417316	269585136	25.416	8.644
617	380689	234885113	24.839	8.513	647	418609	270840023	25.436	8.649
618	381924	236029032	24.859	8.517	648	419904	272097792	25.455	8.653
619	383161	237176659	24.879	8.522	649	421201	273359449	25.475	8.657
620	384400	238328000	24.899	8.527	650	422500	274625000	25.495	8.662
621	385641	239483061	24.919	8.531	651	423801	275894451	25.514	8.666
622	386884	240641848	24.939	8.536	652	425104	277167808	25.534	8.671
623	388129	241804367	24.959	8.540	653	426409	278445077	25.553	8.675
624	389376	242970624	24.979	8.545	654	427716	279726264	25.573	8.680
625	390625	244140625	25.0	8.549	655	429025	281011375	25.592	8.684
626	391876	245314376	25.019	8.554	656	430336	282300416	25.612	8.688
627	393129	246491883	25.039	8.558	657	431649	283593393	25.632	8.693
628	394384	247673152	25.059	8.563	658	432964	284890312	25.651	8.697
629	395641	248858189	25.079	8.568	659	434281	286191179	25.670	8.702
630	396900	250047000	25.099	8.572	660	435600	287496000	25.690	8.706

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
661	436921	288804781	25.709	8.710	691	477481	329939371	26.286	8.840
662	438244	290117528	25.729	8.715	692	478864	331373888	26.305	8.845
663	439569	291434247	25.748	8.719	693	480249	332812557	26.324	8.849
664	440896	292754944	25.768	8.724	694	481636	334255384	26.343	8.853
665	442225	294079625	25.787	8.728	695	483025	335702375	26.362	8.857
666	443556	295408296	25.806	8.732	696	484416	337153536	26.381	8.862
667	444889	296740963	25.826	8.737	697	485809	338608873	26.400	8.866
668	446224	298077632	25.845	8.741	698	487204	340068397	26.419	8.870
669	447561	299418309	25.865	8.745	699	488601	341532099	26.438	8.874
670	448900	300763000	25.884	8.750	700	490000	343000000	26.457	8.879
671	450241	302111711	25.903	8.754	701	491401	344472101	26.476	8.883
672	451584	303464448	25.922	8.759	702	492804	345948408	26.495	8.887
673	452929	304821217	25.942	8.763	703	494209	347428927	26.514	8.891
674	454276	306182024	25.961	8.767	704	495616	348913664	26.533	8.895
675	455625	307546875	25.980	8.772	705	497025	350402625	26.551	8.900
676	456976	308915776	26.0	8.776	706	498436	351895816	26.570	8.904
677	458329	310288733	26.019	8.780	707	499849	353393243	26.389	8.908
678	459684	311665752	26.038	8.785	708	501264	354894917	26.608	8.912
679	461041	313046839	26.057	8.789	709	502681	356400829	26.627	8.916
680	462400	314432000	26.076	8.793	710	504100	357911000	26.645	8.921
681	463761	315821241	26.095	8.797	711	505521	359425431	26.664	8.925
682	465124	317214568	26.115	8.802	712	506944	360944128	26.683	8.929
683	466489	318611987	26.134	8.806	713	508369	362467097	26.702	8.933
684	467856	320013504	26.153	8.810	714	509796	363994344	26.720	8.937
685	469225	321419125	26.172	8.815	715	511225	365525875	26.739	8.942
686	470596	322828856	26.191	8.819	716	512656	367061696	26.758	8.946
687	471969	324242703	26.210	8.823	717	514089	368601813	26.776	8.950
688	473344	325660672	26.229	8.828	718	515524	370146232	26.795	8.954
689	474721	327082769	26.248	8.832	719	516961	371694959	26.814	8.958
690	476100	328509000	26.267	8.836	720	518400	373248000	26.832	8.962

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
721	519841	374805361	26.851	8.966	751	564001	423564751	27.404	9.089
722	521284	376367048	26.870	8.971	752	565504	425259008	27.422	9.093
723	522729	377933067	26.888	8.975	753	567009	426957777	27.440	9.097
724	524176	379503424	26.907	8.979	754	568516	428661064	27.459	9.101
725	525625	381078125	26.925	8.983	755	570025	430368875	27.477	9.105
726	527076	382657176	26.944	8.987	756	571536	432081216	27.495	9.109
727	528529	384240583	26.962	8.991	757	573049	433798093	27.513	9.113
728	529984	385828352	26.981	8.995	758	574564	435519512	27.531	9.117
729	531441	387420489	27.0	9.0	759	576081	437245479	27.549	9.121
730	532900	389017000	27.018	9 004	760	577600	438976000	27.568	9.125
731	534361	390617891	27.037	9.008	761	579121	440711081	27.586	9.129
732	535824	392223168	27.055	9.012	762	580644	442450728	27.604	9.133
733	537289	393832837	27.073	9.016	763	582169	444194947	27.622	9.137
734	538756	395446904	27.092	9.020	764	583696	445943744	27.640	9.141
735	540225	397065375	27.110	9.024	765	585225	447697125	27.658	9.145
736	541696	398688256	27.129	9.028	766	586756	449455096	27.676	9.149
737	543169	400315553	27.147	9.032	767	588289	451217663	27.694	9.153
738	544644	401947272	27.166	9.036	768	589824	452914832	27.712	9.157
739	546121	403583419	27.184	9.040	769	591361	454756609	27.730	9.161
740	547600	405224000	27.202	9.045	770	592900	456533000	27.748	9.165
741	549081	406869021	27.221	9.049	771	594441	458314011	27.766	9.169
742	550564	408518488	27.239	9.053	772	595984	460099648	27.784	9.173
743	552049	410172407	27 258	9.057	773	597529	461889917	27.802	9.177
744	553536	411830784	27.276	9.061	774	599076	463684824	27.820	9.181
745	555025	413493625	27.294	9.065	775	600625	465484375	27.838	9.185
746	556516	415160936	27.313	9.069	776	602176	467288576	27.856	9.189
747	558009	416832723	27.331	9.073	777	603729	469097433	27.874	9.193
748	559504	418508992	27.349	9.077	778	605284	470910952	27.892	9.197
749	561001	420189749	27.367	9.081	779	606841	472729139	27.910	9.201
750	562500	421875000	27.386	9.085	780	608400	474552000	27.928	9.205

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
781	609961	476379541	27.946	9.209	811	657721	533411731	28.478	9.325
782	611524	478211768	27.964	9.213	812	659344	535387328	28.495	9.329
783	613089	480048687	27.982	9.216	813	660969	537367797	28.513	9.333
784	614656	481890304	28.0	9.220	814	662596	539353144	28.530	9.337
785	616225	483736625	28.017	9.224	815	664225	541343375	28.548	9.340
786	617796	485587656	28.035	9.228	816	665856	543338496	28.565	9.344
787	619369	487443403	28.053	9.232	817	667489	545338513	28.583	9.348
788	620944	489303872	28.071	9.236	818	669124	547343432	28.600	9.352
789	622521	491169069	28.089	9.240	819	670761	549353259	28.618	9.356
790	624100	493039000	28.106	9.244	820	672400	551368000	28.635	9.359
791	625681	494913671	28.124	9.248	821	674041	553387661	28.653	9.363
792	627264	496793088	28.142	9.252	822	675684	555412248	28.670	9.367
793	628849	498677257	28.160	9.256	823	677329	557441767	28.687	9.371
794	630436	500566184	28.178	9.259	824	678976	559476224	28.705	9.375
795	632025	502459875	28.195	9.263	825	680625	561515625	28.722	9.378
796	633616	504358336	28.213	9.267	826	682276	563559976	28.740	9.382
797	635209	506261573	28.231	9.271	827	683929	565609283	28.757	9.386
798	636804	508169592	28.248	9.275	828	685584	567663552	28.774	9 390
799	638401	510082399	28.266	9.279	829	687241	569722789	28.792	9.394
800	640000	512000000	28.284	9.283	830	688900	571787000	28.809	9.397
801	641601	513922401	28.301	9.287	831	690561	573856191	28.827	9.401
802	643204	515849608	28.319	9.290	832	692224	575930368	28.844	9.405
803	644809	517781627	28.337	9.294	833	693889	578009537	28.861	9.409
804	646416	519718464	28.354	9.298	834	695556	580093704	28.879	9.412
805	648025	521660125	28.372	9.302	835	697225	582182875	28.896	9.416
806	649636	523606616	28.390	9.306	836	698896	584277056	28.913	9.420
807	651249	525557943	28.407	9.310	837	700569	586376253	28.930	9.424
808	652864	527514112	28.425	9.314	838	702244	588480472	28.948	9.427
809	654481	529475129	28.442	9.317	839	703921	590589719	28.965	9.431
810	656100	531441000	28.460	9.321	840	705600	592704000	28.982	9.435

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
841	707281	594823321	29.0	9.439	871	758641	660776311	29.512	9.550
842	708964	596947688	29.017	9.442	872	760384	663054848	29.529	9 553
843	710649	599077107	29.034	9.446	873	762129	665338617	29.546	9.557
844	712336	601211584	29 051	9.450	874	763876	667627624	29.563	9.561
845	714025	603351125	29.068	9.454	875	765625	669921875	29.580	9.564
846	715716	605495736	29.086	9.457	876	767376	672221376	29.597	9.568
847	717409	607645423	29.103	9.461	877	769129	674526133	29.614	9.571
848	719104	609800192	29.120	9.465	878	770884	676836152	29.631	9.575
849	720801	611960049	29.137	9.468	879	772641	679151439	29.647	9.579
850	722500	614125000	29.154	9.472	880	774400	681472000	29.664	9.582
851	724201	616295051	29.171	9.476	881	776161	683797841	29.681	9.586
852	725904	618470208	29.189	9.480	882	777924	686128968	29.698	9.590
853	727609	620650477	29.206	9.483	883	779689	688465387	29.715	9.593
854	729316	622835864	29.223	9.487	884	781456	690807104	29.732	9.597
855	731025	625026375	29.240	9.491	885	783225	693154125	29.748	9.600
856	732736	627222016	29.257	9.494	886	784996	695506456	29.765	9.604
857	734449	629422793	29.274	9.498	887	786769	697864103	29.782	9.608
858	736164	631628712	29.291	9.502	888	788544	700227072	29.799	9.611
859	737881	633839779	29.308	9.506	889	790321	702595369	29 816	9.615
860	739600	636056000	29.325	9.509	890	792100	704969000	29 832	9.619
861	741321	638277381	29.342	9 513	891	793881	707347971	29.849	9.622
862	743044	640503928	29.359	9.517	892	795664	709732288	29.866	9.626
863	744769	642735647	29.376	9.520	893	797449	712121957	29.883	9.629
864	746496	644972544	29.393	9 524	894	799236	714516984	29.899	9.633
865	748225	647214625	29.410	9.528	895	801025	716917375	29.916	9.636
866	749956	649461896	29.427	9 531	896	802816	719323136	29.933	9.640
867	751689	651714363	29.444	9.535	897	804609	721734273	29.949	9.644
868	753424	653972032	29.461	9.539	898	806404	724150792	29.966	9.647
869	755161	656234909	29.478	9.542	899	808201	726572699	29.983	9.651
870	756900	658503000	29.495	9.546	900	810000	729000000	30.0	9.654

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
901	811801	731432701	30.016	9.658	931	866761	806954491	30.512	9.764
902	813604	733870808	30.033	9.662	932	868624	809557568	30.528	9.767
903	815409	736314327	30.049	9.665	933	870489	812166237	30.545	9.771
904	817216	738763264	30.066	9.669	934	872356	814780504	30.561	9.774
905	819025	741217625	30.083	9.672	935	874225	817400375	30.577	9.778
906	820836	743677416	30.099	9.676	936	876096	820025856	30.594	9.781
907	822649	746142643	30.116	9.679	937	877969	822656953	30.610	9.785
908	824464	748613312	30.133	9.683	938	879844	825293672	30.626	9.788
909	826281	751089429	30.149	9.686	939	881721	827936019	30.643	9.792
910	828100	753571000	30.166	9.690	940	883600	830584000	30.659	9.795
911	829921	756058031	30.182	9.694	941	885481	833237621	30.675	9.799
912	831744	758550528	30.199	9.697	942	887364	835896888	30.692	9.802
913	833569	761048497	30.215	9.701	943	889249	838561807	30.708	9.806
914	835396	763551944	30.232	9.704	944	891136	841232384	30.724	9.809
915	837225	766060875	30.248	9.708	945	893025	843908625	30.740	9.813
916	839056	768575296	30.265	9.711	946	894916	846590536	30.757	9.816
917	840889	771095213	30.282	9.715	947	896809	849278123	30.773	9.820
918	842724	773620632	30.298	9.718	948	898704	851971392	30.789	9.823
919	844561	776151559	30.315	9.722	949	900601	854670349	30.805	9.827
920	846400	778688000	30.331	9.725	950	902500	857375000	30.822	9.830
921	848241	781229961	30.347	9.729	951	904401	860085351	30.838	9.833
922	850084	783777448	30.364	9.732	952	906304	862801408	30.854	9.837
923	851929	786330467	30.380	9.736	953	908209	865523177	30.870	9.840
924	853776	788889024	30.397	9.739	954	910116	868250664	30.886	9.844
925	855625	791453125	30.413	9.743	955	912025	870983875	30.903	9.847
926	857476	794022776	30.430	9.746	956	913936	873722816	30.919	9.851
927	859329	796597983	30.446	9.750	957	915849	876467493	30.935	9.854
928	861184	799178752	30.463	9.754	958	917764	879217912	30.951	9.857
929	863041	801765089	30.479	9.757	959	919681	881974079	30.967	9.861
930	864900	804357000	30.495	9.761	960	921600	884736000	30.983	9.864

SQUARES, CUBES, SQUARE ROOTS, AND CUBE ROOTS—*Continued.*

No.	Square.	Cube.	Square Root.	Cube Root.	No.	Square.	Cube.	Square Root.	Cube Root.
961	923521	887503681	31.0	9.868	981	962361	944076141	31.320	9.936
962	925444	890277128	31.016	9.871	982	964324	946966168	31.336	9.939
963	927369	893056347	31 032	9.875	983	966289	949862087	31.352	9.943
964	929296	895841344	31.048	9 878	984	968256	952763904	31.368	9.946
965	931225	898632125	31.064	9.881	985	970225	955671625	31.384	9.949
966	933156	901428696	31.080	9.885	986	972196	958585256	31.400	9.953
967	935089	904231063	31.096	9.888	987	974169	961504803	31.416	9.956
968	937024	907039232	31.112	9.892	988	976144	964430272	31.432	9.959
969	938961	909853209	31.128	9.895	989	978121	967361669	31.448	9.963
970	940900	912673000	31.144	9.898	990	980100	970299000	31.464	9.966
971	942841	915498611	31.160	9.902	991	982081	973242271	31.480	9.969
972	944784	918330048	31.176	9.905	992	984064	976191488	31.496	9.973
973	946729	921167317	31.192	9.909	993	986049	979146657	31.511	9.976
974	948676	924010424	31.208	9.912	994	988036	982107784	31.527	9.979
975	950625	926859375	31.225	9.915	995	990025	985074875	31.543	9.983
976	952576	929714176	31.241	9.919	996	992016	988047936	31.559	9.986
977	954529	932574833	31.257	9.922	997	994009	991026973	31.575	9.989
978	956484	935441352	31.272	9.926	998	996004	994011992	31.591	9 993
979	958441	938313739	31.288	9.929	999	998001	997002999	31.606	9.996
980	960400	941192000	31.304	9.932	1000	1000000	1000000000	31.622	10.0

RECIPES.

To Clean Brass, etc.

Powdered rottenstone, ½ lb.
Soft soap, ½ lb.
Oil of vitriol, 4 drops.
Sweet oil, 1 teaspoonful.
Turpentine, 1 tablespoonful.

Mix in a basin with a wooden spoon or stick, and keep in a jar. Put on with a piece of flannel, and while damp rub off with a piece of soft linen. Polish with leather dipped in fine dry whiting.

White-wash.

For Indoor Work.—2 lbs. Paris whiting, 1 oz. white glue; dissolve the glue in warm water. Mix whiting with warm water, stir in glue, thin with warm water.

For Outside Work.—Slack 1 peck of lime with water. While hot, add ½ pound of tallow or other grease, stir thoroughly—will stand rain.

Anti-friction Grease.

Boil together 1¾ cwt. of tallow with 1¼ cwt. of palm oil. When boiling point is reached allow it to cool to blood heat, stirring it meanwhile, then strain through a sieve into a solution of ½ cwt. of soda in 3 gallons of water, mixing it well.

The above is for summer.

For winter—1¼ cwt. of tallow to 1¾ cwt. palm oil.

Spring and autumn—1½ cwt. of tallow to 1½ cwt. palm oil.

Mixture to Cool Hot Journals.

11 lbs. black lead,
23 " epsom salt,
9 " sulphur,
2 " lamp black,
5 " oxalic acid.

The ingredients to be pulverized, mixed, and ground together.

Foundry Recipes.

Fire-clay crucibles—2 Stourbridge clay,
1 Hard gas coke, finely powdered.
Berlin crucibles—8 Stourbridge clay,
3 Old crucibles, ground finely,
5 Coke,
4 Graphite, or "black lead."
Black-lead crucibles—1 Fire-clay,
2 Graphite.

Parting Sand.

Burnt sand scraped from the surface of castings.

Loam.

Mixture of brick clay and old foundry sand.

Blackening for Moulds.

Charcoal powder; or, in some instances, fine coal dust.

Black Wash.

Charcoal, plumbago, and size.

Mixture for Welding Steel.

1 Sal ammoniac,
10 Borax,

Pounded together, and fused until clear, when it is poured out, and, when cool, reduced to powder.

Brazing.

The edges filed or scraped clean and bright, covered with spelter and powdered borax, and exposed in a clear fire to a heat sufficient to melt the solder.

Tempering Steel.

Color.	Purpose.	Temperature.	Alloy whose fusing point is of the same temp.
		Fah.	Tin. Lead.
Light straw...	Turning tools for metal.....	430°	1 to 1¾
Dark straw...	Wood tools, taps, and dies.....	470°	1 to 2½
Brown yellow.	Hatchets, chipping chisels.....	500°	1 to 4¾
Dark purple ..	Springs, etc.....	550°	1 to 12

Case-Hardening.

Horn, hoof, bone dust, or shreds of leather, heated together with the article to be case-hardened, in an iron box, to a blood red heat, then immerse the article in cold water.

Some engineers cut up the shreds, etc., fine, and mix them with white-wine vinegar and salt.

Case-Hardening with Prussiate of Potash.

Heat the articles, after polishing, to a bright red, rub the surface over with prussiate of potash; allow it to cool to dull red, and immerse it in water.

Case-Hardening Mixtures.

3 of prussiate of potash to 1 of sal ammoniac, mixed; or, 2 of sal ammoniac, 2 of bone dust, and 1 of prussiate of potash.

Rust Joint Cement (*Quickly Setting*).

1 Sal ammoniac in powder (by weight).
2 Flower of sulphur.
80 Iron borings made to a paste with water.

Rust Joint (*Slowly Setting*).

2 Sal ammoniac.
1 Flower of sulphur.
200 Iron borings.

The latter cement is the best if the joint is not required for immediate use.

Red Led Cement for Face Joints.

1 of white lead.
1 of red lead, mixed with linseed oil to the proper consistency.

Glue to Resist Moisture.

1 lb. of glue melted in 2 quarts of skimmed milk.

When strong glue is required, add powdered chalk to common glue.

Marine Glue.

1 of india-rubber, 12 of mineral naphtha or coal tar, heat gently, mix, and add 20 of powdered shellac. Pour out on a slab to cool; when used to be heated to about 250°.

Glue Cement to Resist Moisture.

1 glue,
1 black resin, } Mixed with the least possible quantity of water;
¼ red ochre,

OR,

4 of glue,
1 of boiled oil by weight,
1 oxide of iron.

Cement for Cloth or Leather.

16 gutta percha, cut small,
4 india-rubber, "
2 pitch, "
1 shellac, "
2 linseed oil, "
} melted together, and well mixed.

Dubbing.

2 lbs. black resin, 1 lb. tallow, 1 gallon train oil.

Iron Lacquer.

12 of amber,
12 of turpentine,
2 of resin,
2 of asphaltum,
6 of drying oil;

OR,

3 lbs. of asphaltum,
½ lb. shellac,
1 gallon of turpentine.

Brass Lacquer.

8 ounces of shellac,
2 ounces of sandarac,
2 ounces of annatto,
¼ ounce of dragon's blood resin,
1 gallon of spirits of wine;

OR,

8 ounces of shellac,
1 gallon of spirits of wine.

The article to be lacquered should be heated slightly, and the lacquer should be applied by means of a soft camel's hair brush.

Black Ink—*Anti-corrosive and Neutral.*

42 ounces powdered nutgall,
15 ounces gum senegal,
18 ounces sulphate of iron, free from copper,
3 drachms aqua ammonia,
24 ounces alcohol,
18 quarts rain water.

Digest in an open vessel until fluid has a deep black color.

Permanent Ink for Zinc Labels.

6 grains sulphate of copper. Dissolve in 1 ounce of water. Add 3 grains sal ammoniac, 20 drachms sulphuric acid. Use a quill or gold pen.

Colored Fires for Illuminations.

Red Fire.

Nitrate of Strontia	6.75 lbs.
Chlorate of Potassa	.45 "
Charcoal, powdered	.57 "
Sulphur flowers	2.00 "
	9.77 "

Green Fire.

Nitrate of baryta	12 lbs.
Chlorate of potassa	5 "
Sulphur flowers	4 "
	21 "

The nitrate of strontia should be dried on a tin pan in the oven, at a low temperature, and not allowed to melt.

The ingredients should be mixed as shown in brackets (kneaded with the hands only), no violence used, or explosion will ensue. The nitrates of strontia and baryta to be finely pulverized.

To be kept in a dry place, but not allowed to stand long, for fear of spontaneous combustion.

Paper for Draughtsmen.

Powdered tragacanth, 1 part; water, 10 parts. Dissolve and strain through clean gauze. Lay it smoothly, with a painter's brush, on the paper previously stretched on a board. This paper will take oil or water colors.

Parchment Paper.

Dip white unsized paper, for half a minute, in strong sulphuric acid, and afterwards in water containing a little ammonia. When dried will look like and be as strong as parchment.

Rules for the Course to be Followed by the Bystanders in Case of Injury by Machinery, when Surgical Assistance cannot be At Once Obtained.

The dangers to be feared in these cases are: *Shock or collapse, loss of blood, and unnecessary suffering in the moving of the patient.*

I. In SHOCK the injured person lies pale, faint, cold, sometimes insensible, with labored pulse and breathing.

Apply external warmth, by wrapping him up (not merely covering him over) in blankets, quilts, or extra clothes. Bottles of hot water, hot bricks (not too hot) may also be wrapped up in cloths and put to the arm-pits along the sides and between the feet, if they are uninjured.

If the patient has NOT been drinking, give brandy or whiskey in *table-spoonful* doses every 15 or 20 minutes—less frequently as he gets better. Food (strong soup is the best) should also be given now and then.

II. LOSS OF BLOOD.—If the patient is NOT bleeding, *do not* apply any constriction to the limb, but cover the wounded part lightly with the softest rags to be had (linen is the best).

If there is bleeding do not try to stop it by binding up the the wound. *The current of the blood to the part must be checked.* To do this, find the artery, by its beating; lay a firm and even compress or pad (made of cloth or rags rolled up, or a round stone or piece of wood well wrapped) OVER THE ARTERY (*see Figure* 1); tie a handkerchief around the limb and compress; put a bit of stick thro' the handkerchief and twist the latter up until it is *just tight enough to stop the bleeding*; then put one end of the stick under the handkerchief to prevent untwisting, *as in Figure* 2.

Fig. 1.

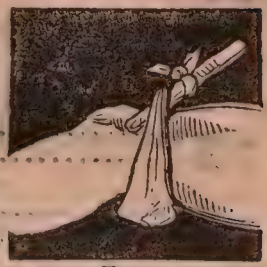


Fig. 2.

The artery in the thigh runs along the inner side of the muscle in front, near the bone. A little above the knee, it passes to the back of the bone. In injuries at or above the knee, apply the compress high up, on the inner side of the

Fig. 5—Arm.

Fig. 3—Leg.

thigh, at the point where the two thumbs meet at C in Figure 3, with the knot on the outer side of the thigh. When the leg is injured below the knee, apply the compress at the back of the thigh just above the knee at C, in Figure 4, and the knot in front, as in Figures 1 and 2.

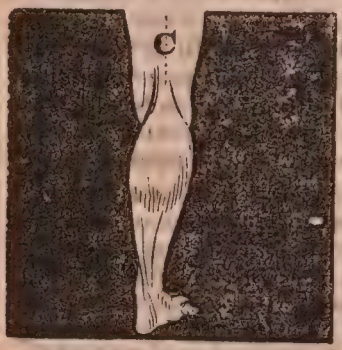


Fig. 4.

The artery in the arm runs down the inner side of the large muscle in front, quite close to the bone; low down it gets further forward toward the bend of the elbow. It is most easily found and compressed a little above the middle (*see Figure 5*).

Care should be taken to examine the limb from time to time, and to lessen the compression if it becomes very cold or purple; tighten up the handkerchief again if the bleeding begins afresh.

III. To Transport a Wounded Person Comfortably. Make a soft and even bed for the injured part, of straw, folded blankets, quilts, or pillows laid on a board, with side-pieces of board nailed on, where this can be done. If possible let the patient be laid on a door, shutter, settee, or some firm support, properly covered. Have sufficient force to lift him steadily, and let those who bear him NOT keep step.

IV. Should any important arteries be opened, apply the handkerchief as recommended. Secure the vessel by a surgeon's dressing forceps, or by a hook, then have a silk ligature put around the vessel, and tighten tight.

V. Should the bleeding be from arterial vessels of small size, apply the PERSULPHATE of IRON, either in tincture or in powder, by wetting a piece of lint or sponge with the solution; then, after bleeding ceases, apply a compress against the parts to sustain them during the application of the persulphate of iron, and to prevent further bleeding should it occur. The persulphate of iron should be kept on hand in all workshops.

Send for a physician in all cases.

For Burns or Scalds.

In the early stage, soon after the accident, if there is no separation of the skin, do not cut the bladder, but allow the *bladder* of *water*, of whatever size, to remain untouched; merely dress it with a piece of linen or muslin, lightly coated with simple cerate.

If the parts are denuded of the skin, dress the part with cotton, the object being to exclude the air and prevent suppuration. If cotton cannot be procured, apply any covering until you can have an ointment made of beeswax and sweet oil, equal parts, or lime water and linseed oil; or lay on scraped potatoes or carrots, or sprinkle flour on the injured surface when the above cannot be procured. Flour is troublesome in its removal.

If the scald is extensive and on the body, COLD APPLICATIONS are NOT PROPER; then use warm fomentations, or, in the case of a child, the WARM BATH. Keep the air from the wound as

much as possible; do not remove the dressing often. When a cold lotion is used, pour it upon the rags, letting them remain undisturbed.

Bruises.

Use tepid applications at first. After inflammation has subsided, use stimulating applications, as vinegar and water, alcohol, camphorated liniment.

Sprains.

Elevate the limb; keep the joint perfectly quiet; apply lukewarm lotions or fomentations. When inflammation has ceased, apply stimulating liniments and bandages; shower the part with cold water, alternating with warm water.

To Restore Persons Affected by Cold.

For Frost-Bite or Numbness—Restore warmth *gradually*, in proportion as circulation in the parts or body increases.

For a Frozen Limb.—Rub with snow, and place in cold water for a short time. When sensation returns, place again in cold water; add heat *very gradually*, by adding warm water.

If Apparently Dead or Insensible.—Strip entirely of clothes, and cover body, with exception of mouth and nostrils, with snow or ice-cold water. When body is thawed, dry it, place it in a cold bed; rub with warm hands under the cover; continue this for hours. If life appears, give small injections of camphor and water; put a drop of spirits of camphor on tongue; then rub body with spirits and water, finally with spirits; then give tea, coffee, or brandy and water.

Send for a physician in all cases.

Apparent Death from Breathing Noxious Vapor, as in Wells, &c.

If insensible, expose person to the open air; sprinkle cold water on face and head; rub strong vinegar about nostrils; give

Ramapo Wheel and Foundry Co.

drink of vinegar and water. If suffocated by breathing fumes of charcoal, proceed as above, and excite breathing as in remedy given in cases of drowning.

Send for a physician in all cases.

To purify wells, &c., shower water down them until a candle will burn at the bottom with a clear flame.

Rules for Accidents on Water.

When upset in a boat, or thrown into the water and unable to swim, draw the breath in well; keep the mouth tight shut; do not struggle and throw the arms up, but yield quietly to the water; hold the head well up, and stretch out the hands only *below* the water; to throw the hands or feet *up* will pitch the head *down*, and cause the whole person to go immediately under water. Keep the head *above*, and everything else under water.

Method to be Used in Cases of Drowning.

DR. MARSHALL HALL'S REMEDY.

Send for a Physician in all Cases.

1*st*. Treat the patient INSTANTLY ON THE SPOT, in the OPEN AIR, freely exposing the face, neck, and chest to the breeze, except in severe weather.

2*d*. In order to CLEAR THE THROAT, place the patient gently on the face, with one wrist under the forehead, that all fluid, and the tongue itself, may fall forward, and leave the entrance into the windpipe free.

3*d*. To EXCITE RESPIRATION, turn the patient slightly on his side, and apply some irritating or stimulating agent to the nostrils, as VERATRINE, DILUTE AMMONIA, etc.—as snuff, or apply a feather to the throat.

4*th*. Make the face warm by brisk friction; then dash cold water upon it.

5*th*. If not successful, lose no time; but, TO IMITATE RESPIRATION, place the patient on his face, and turn the body gently, but completely ON THE SIDE, AND A LITTLE BEYOND; then again on the face, and so on alternately. Repeat these move-

ments deliberately and perseveringly FIFTEEN TIMES ONLY in a minute. (When the patient lies on the breast, this cavity is COMPRESSED by the weight of the body, and *ex*piration takes place. When he is turned on the side this pressure is removed, and *in*spiration occurs.)

6th. When the prone position is resumed, make a uniform and efficient pressure ALONG THE SPINE, removing the pressure immediately, before rotation on the side. (The pressure augments the *ex*piration; the rotation commences *in*spiration.) Continue these measures.

7th. Rub the limbs UPWARD with FIRM PRESSURE, and with ENERGY. (The object being to aid the return of venous blood to the heart.)

8th. Substitute for the patient's wet clothing, if possible, such other covering as can be instantly procured, each bystander supplying a coat or cloak, &c. Meantime, and from time to time, TO EXCITE INSPIRATION, let the surface of the body be SLAPPED briskly with the hand.

9th. Rub the body briskly till it is dry and warm, then dash COLD water upon it, and repeat the rubbing.

AVOID the immediate removal of the patient, as it involves a DANGEROUS LOSS OF TIME; also, the use of bellows, or any FORCING instrument; also, the WARM BATH, and ALL ROUGH TREATMENT.

SUN-STROKE.

Take patient immediately into the shade; place in a half recumbent position—head raised; loosen clothes about neck and chest; apply, immediately, ice or cold wet cloths to the head and nape of the neck, changing them frequently.

Send for a physician as soon as possible.

POISONS AND ANTIDOTES.

1st—Send for a Physician immediately.

In all cases of poisoning, the first step is to evacuate the stomach. This should be effected by an emetic which is *quickly* obtained, and most powerful and speedy in its operation: such

are—powdered mustard (a large teaspoonful in a tumbler-full of water), or salt, or ½ teaspoonful powdered ipecac every 10 to 15 minutes.

When vomiting has already taken place, copious draughts of warm water, or warm mucilaginous drinks, should be given, to keep up the effect till the poisoning substance has been thoroughly evacuated. If vomiting cannot be produced, the stomach-pump must be used. This instrument will be particularly useful when narcotics, in liquid form, have been taken. In cases of corrosive poisoning it is liable to lacerate the stomach.

Poisons.	Antidotes.
Acids	The alkalies; common soap (soft or hard), in solution, is a good remedy. It should be followed by copious draughts of tepid water or flaxseed tea For *nitric* and *oxalic* acids, chalk and water are the best antidotes. When sulphuric acid has been taken, the use of much water is improper.
Alkalies and their Salts	The vegetable acids; common vinegar is most frequently used. Oils, as castor, flaxseed, almond and olive oils, form soaps with the alkalies, and destroy their caustic effect; should be given in *large quantities.*
Prussic Acid	Chlorine water, solution of chlorinated soda, aqua ammonia; cold effusion.
Iodine—Iodide of Potassium	Starch, wheat flour, or arrow-root, in large quantities, well mixed with water; drink freely of them; afterward, strong mixture of vinegar and water. When this is done, life will be saved.
Antimony and its Salts — Tartar Emetic	Astringent infusions, as of galls, oak bark, Peruvian bark, STRONG green tea.

Richmond Iron.

Arsenic and its Compounds .... Any oil or fat (sweet oil, buttermilk); magnesia in large quantities.

Bismuth ..... Albumen; copious draughts of milk, with sweet mucilaginous drinks.

Copper and its Compounds—

Verdigris ..... Albumen, as milk or white of eggs, in solution, freely used; ferrocyanuret of potassium (freely). *Vinegar must be avoided.*

Gold, Salts of.... Sulphate of iron and mucilaginous drinks.

Iron, Salts of .... Carbonate of soda and mucilaginous drinks.

Lead, Salts of ... Albumen; Epsom salts, Glauber's salts; lemonade.

Mercury, Salts of—

Corrosive Sublimate ..... Albumen, as white of eggs, milk, or wheat flour beaten up with water; followed by an emetic.

Silver, Salts of .. Common salt, freely, in solution.

Tin, Salts of .... Albumen: white of eggs, milk, or flour.

Zinc, Salts of.... Albumen, or carbonate of soda, with copious draughts of warm water, and especially milk.

Phosphorus ..... Magnesia, with water, and copious draughts of mucilaginous drinks.

Gases ..... Ammonia, cautiously inhaled, is recommended for chlorine. Asphyxia, from noxious gases, must be treated by cold effusions to the head, blood-letting, artificial respiration, and stimulants carefully administered.

Creosote..... White of egg, milk, wheat flour.

Alcohol ..... A powerful emetic to be given, followed by copious draughts of warm water.

Opium—Morphine
—Laudanum—
Strychnine . . . . Use most active emetics—mustard, alum—stomach-pump; 2 drops tincture belladonna every hour, for three or four hours. Patient must be kept in motion; slapped or flagellated; cold water dashed on head and shoulders.

Poison from Ivy.

Ivy . . . . . Wash affected part with solution of sugar of lead, 20 grains, to a pint of water.

Snake-Bites.

Snake-Bites . . . . . Suck the wound immediately; give stimulants even to intoxication, if there is prostration.

Send for a physician in all cases.

Rules for Treatment of Cholera.

(*Metropolitan Board of Health.*)

Cholera is almost invariably preceded by a painless diarrhœa, and this is in all cases to be promptly treated.

When diarrhœa is present, go to bed and maintain a position on the back; use abundance of blankets, and send for a physician.

Stay in bed until you are well; do not consider yourself well until you have had a natural movement from the bowels. Abstain from all drinks. Apply mustard plasters to the bowels.

In the absence of a physician, an adult can take ten drops of laudanum, and ten drops of spirits of camphor. A child of ten years, may take five drops of laudanum and five of camphor. A child of five years, may take three drops of laudanum and three of spirits of camphor; and these doses may be repeated every twenty minutes, so long as diarrhœa, or pain or vomiting continues.

This will save time, *but in all cases send for a physician.*

Do not get up to pass the evacuations, but use the bed-pan

or other conveniences. *Never chill the surface of the body by getting out of bed.*

Remove immediately all the evacuations from your rooms. Scald all the utensils used, or disinfect them with chloride of lime; scald also your soiled clothing.

Diarrhœa.

Tincture of capsicum, 1 ounce; laudanum, ¼ ounce. Mix. Dose for an adult, 40 drops (or half a teaspoonful) after each evacuation, in a little water; if there is much pain, apply a mustard plaster to the stomach and bowels, or lay a cloth saturated with above mixture on parts, if mustard plaster is not readily procured.

Fever and Ague.

Fever and ague is always preceded by an ague fit; has three stages: 1st—The cold, when teeth chatter; 2d—The hot, with high fever; 3d—The sweating, when moisture appears and feeling of health returns. *Consult a physician.* If one can not be obtained, in cold stage give *hot* drinks, hot foot-bath, hot bottles to sides and limbs.

In hot stage, give *cooling* drinks—½ teaspoonful of sweet spirits of nitre, in water, every two hours.

During sweating stage, rub patient with a dry towel.

In *intermission* between chills, give quinine in 2-grain doses, every three hours; when ten doses are taken, then give 10 drops of the tincture of iron, three times a day, for a week. Avoid the hot sun and damp evening and morning air. Where fever prevails, high hills, and upper floors of dwellings are the healthiest.

UNITED STATES PATENTS AND FEES.

No patent will be granted if the whole or any part of what is claimed has been patented or described in any printed publication in this or a foreign country, or been invented or discovered in this country.

Prior invention abroad will not prevent issue of a patent, unless the invention has been there patented or described in some printed publication.

To prevent a subsequent inventor from obtaining a patent, an invention must have been reduced to a practical form, either by construction of a model or machine, or drawing, by which a mechanic could make the same.

Merely conceiving an idea of an invention is not a discovery, and patentable.

Foreign Patents.—The taking out of a patent in a foreign country does not prejudice a patent previously granted here; nor does it prevent obtaining a patent here subsequently. When a patent is granted here, it will extend only seventeen years from date of foreign patent.

Every foreign inventor must have in use, or for sale in the United States, a copy of their patentable article, within eighteen months from date of patent.

Duration of Patent is seventeen years. Extensions are prohibited on all patents granted since 1861. Applications for extension must be filed, and requisite fee paid, ninety days before expiration of the patent.

Granting of Patents.—Patents, on payment of same official fee, are granted to all persons, including women and minors, unless inhabitants of countries which discriminate against the inhabitants of the United States.

Application for a Patent must be made in name of the *inventor*, who can *alone* sign the papers; an attorney for inventor *can not* do so.

Heirs of an Inventor can obtain a patent, papers to be signed by executor or administrator of inventor.

Joint Inventors are entitled to a joint patent.

An Inventor can assign his entire right, before a patent is obtained, so as to enable the assignee to take out a patent in his own name; but the assignment must be first recorded, and specification sworn to by the inventor.

Oaths may be taken, in this country, before any one authorized by law to administer oaths; in a foreign country, before any minister plenipotentiary, charge d'affaires, consul, commercial agent or notary public of the country in which oath is taken, being in all cases properly attested by official seal of such notary.

Stamps.—A stamp of value of *fifty cents* is required for each power of attorney, each sheet of an assignment to be stamped *five cents*, each certificate of magistrate *five cents*.

Drawings to be in duplicate, one on stiff paper, one on tracing cloth to be 20 inches top to bottom, 15 inches wide; tracing to have 1 inch margin on right hand side, for binding.

Models to be of hard wood or metal, not more than 12 inches in any dimension; name of the inventor to be engraved or painted conspicuously on it.

For an Improvement, only model of part to be patented is required, to show nature and operation of invention.

Designs, no models required; either drawings or photographs, both in duplicate, with *negative* of photograph.

New Articles of manufacture, sample of article; medicines or medical compounds, sample of same, and minute statement of exact proportions and ingredients.

Caveats.

The filing of a caveat prevents, during its existence, the issue of a patent, without the knowledge of the caveator, to any person for a similar devise. The caveator is entitled to receive official notice, during one year, for any petition for similar or interfering invention filed during that time. The caveator, when so notified, must complete his own application within three months from date of notice.

A caveat runs one year; can be extended by paying $10 a year.

Caveats can only be filed by citizens of the United States, or aliens who have resided here one year and declared their intention of becoming citizens.

United States Patent Fees.

On filing each caveat	$10 00
On filing each original application for a patent, except for a design.	15 00
On issuing each original patent	20 00
On every appeal from Examiners-in-Chief	20 00
On application for a reissue	30 00
On application for extension	50 00
Granting an extension	50 00
Filing each disclaimer	10 00
Certified copies of patents and other papers, 10 cents per 100 words.	
Recording every assignment, agreement, power of attorney, and other papers, of 300 words or under	1 00
If over 300 and under 1,000 words	2 00
If over 1,000 words	3 00
Drawings, cost of making same.	
Patents for designs—for three and one-half years	10 00
" " for seven years	15 00
" " for fourteen years	30 00

In addition to the above, Messrs. Munn & Co., Patent Solicitors, N. Y., charge for written report of special examination at Patent Office, if invention has been patented in this country, $5; for general information of infringements, reissues, claims, assignments, joint ownership, contracts, licenses, name in which patent is recorded, abstracts of deeds of transfer, sketch of a drawing of patent, license made out, transfer of do.,

recording do., $5 for each case; for procuring a patent, $25 to $35, or more; for procuring a caveat, $10 to $15; for copies of patents or assignments, or drawings of any existing patents, $5 to $10; copy of any claim, $1.

Foreign Patents.

Great Britain.—Duration, fourteen years, to first inventor or importer; cost, $350, of which $100 due at time of making application, balance in four months; three years from date of patent, a further sum of £50 must be paid; end of seven years, £100 additional. For designs to protect shape of article, three years, $100.

France.—Term of patent, fifteen years; annual fee, $20.

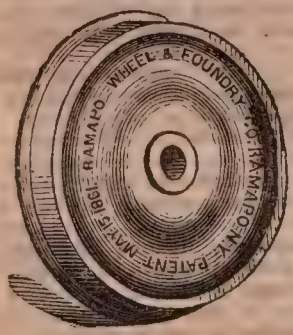
Belgium.—Term of patent, twenty years: small annual fees.

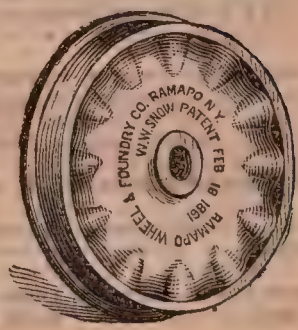
Expense of Foreign Patents, inclusive of all Fees.

Austria	$250	Netherlands	$150
Bavaria	150	Portugal	250
Belgium	150	Prussia	200
Cuba	450	Russia	550
France	150	Saxony	250
Great Britain	350	Spain	400
India	400	Sweden and Norway	600
Italy	250		

Much expense and time are saved by entrusting all patent business to reliable patent solicitors. Messrs. Munn & Co., 37 Park row, New York, on application, will furnish, for twenty-five cents, their book on patents—a valuable aid to the inventor.

PATENT WHEELS MADE AT RAMAPO.





Richmond Iron.

STAMP DUTIES,

IMPOSED BY ACT OF CONGRESS,

As Amended by Act of June 30, 1864, *to take effect August* 1, 1864.

GENERAL REMARKS.

Revenue stamps may be used indiscriminately upon any of the matters or things enumerated below, except proprietary and playing-card stamps, for which a special use has been provided.

Postage stamps cannot be used in payment of the duty chargeable on instruments.

It is the duty of the maker of an instrument to affix and cancel the stamp required thereon. If he neglects to do so, the party for whose use it is made may stamp it before it is used; but in no case can it be legally used without a stamp; and if issued after the 1st of June, 1863, and *used* without a stamp, it cannot be afterwards effectually stamped. Any failure upon the part of the maker of an instrument to appropriately stamp it subjects him to a penalty of fifty dollars.

Where there is a sale of land incumbered by a mortgage, without a covenant by the grantee, express or implied, to pay the mortgage debt, the stamp must be appropriate to the consideration of the grant, of which consideration the mortgage will not form a part. Where the grantee assumes to pay the mortgage debt, or takes the land subject to it, that debt is properly estimated as a part of the consideration, and the stamp will be such as is appropriate to the whole value of the land.

A good rule to observe in acknowledging and recording instruments, is to make a note in the acknowledgment, or on the record, of the amount of stamp duty affixed, and the date of cancellation.

When two or more persons join in the execution of an instrument, the stamp to which the instrument is liable under the law may be affixed and cancelled by any one of the parties.

	STAMP DUTY.
Acknowledgment of deeds or other instruments, made before a justice, notary, or other qualified officer.....	Exempt.
Affidavit.....	$ 05
Agreement or Appraisement (for each sheet or piece of paper on which the same is written).....	05
Assignment or transfer of mortgage, lease, or policy of insurance, or the renewal or continuance of any agreement, contract or charter, by letter or otherwise, is subject to the same duty as the original instrument.	
Assignment, ordinary, as of bond, without guarantee.....	Exempt.
" patent right.....	$ 05
Bank Check, draft, or order for the payment of any sum of money whatsoever, drawn upon any bank, banker, or trust	

	STAMP DUTY.
company, or for any sum exceeding $10 drawn upon any other person or persons, companies or corporations, at sight or on demand,	$ 02
Bill of Exchange (inland), draft, or order for the payment of any sum of money (not exceeding $100) otherwise than at sight or on demand, and any promissory note (except bank notes issued for circulation, and checks made and intended to be forthwith presented, and which shall be presented to a bank or banker for payment, or any memorandum, check, receipt, or other written or printed evidence of an amount of money to be paid on demand or at a time designated, shall have a stamp or stamps affixed thereon denoting a duty upon every sum not exceeding $100	05
For every additional $100, or fraction thereof, in excess of $100..	05
Bills of Exchange (foreign), if drawn in sets of three or more, for every bill of each set, where the sum does not exceed $100 or its equivalent thereof in any foreign currency	02
For every additional $100, or fraction thereof, in excess of $100..	02
Bills of Exchange (foreign), drawn in but payable out of the United States (if drawn *singly* or *in duplicate*), pay the same rates of duty as Inland Bills of Exchange. [The acceptor or acceptors of any Bill of Exchange, or order for the payment of any sum of money drawn, or purporting to be drawn, in any foreign country, but payable in the United States, must, before paying or accepting the same, place thereupon a stamp indicating the duty. See Section 159, Act of June 30, 1864.]	
Bills of Lading, of vessels for ports of the United States, or British North America	Exempt.
Bill of Lading or receipt of goods to any foreign port, on every bill of each set	$ 10
Bill of Sale of any vessel or part thereof, when the consideration shall not exceed $500	50
Bill of Sale exceeding $500, and not exceeding $1,000	1 00
" exceeding $1,000, for each $500 or fraction thereof.	50
Bill of Sale of personal property (other than ship or vessel)..	05
Bond indemnifying any person for the payment of any sum of money where the money ultimately recoverable thereupon is $1,000 or less	50
Bond when the money recoverable exceeds $1,000, for every additional $1,000 or fraction thereof in excess of $1,000	50
Bond for the due execution or performance of the duties of any office	1 00

	STAMP DUTY.
Bond for deed or conveyance of land	$ 25
Bonds of any description, other than such as are required in legal proceedings, and such as are not otherwise charged	25
Cards, playing, per pack, of whatever number, whenever the retail price per pack does not exceed 18 cents	02
Cards, playing, over 18 and not over 25 cents per pack	04
" " over 25 and not over 50 cents per pack	10
" " over 50 cents and not over $1	15
" " over $1, for each additional 50 cts. or fraction	05
Certificates of Loan, on which there shall appear any written or printed evidence of an amount of money to be paid on demand, or at a time designated, are subject to stamp duty as "Promissory Notes."	
Certificate of deposit in bank, sum not exceeding $100	02
" of deposit in bank, sum exceeding $100	05
" of stock in an incorporated company	25
" of profits in an incorporated company, for a sum not less than $10 nor exceeding $50	10
Certificate of profits in an incorporated company, for a sum exceeding $50 and not exceeding $1,000	25
Certificate of profits in an incorporated company, exceeding $1,000, for every $1,000, or fractional part thereof	25
Certificate of record upon the instrument recorded	Exempt.
" of record upon the book	Exempt.
" of weight or measurement of animals, coal, wood, or other articles. (Except, see Returns)	Exempt.
Certificate—Any certificate of damage, and all other certificates or documents issued by any port warden, marine surveyor, or other person acting as such, stamp duty	$ 25
Certificates of any other description than those specified, a stamp duty of	05
Certified Transcripts of judgment, satisfaction of judgment, and of all papers recorded, and of papers on file, each... [N. B.—As a general rule, every certificate which has, or may have, a legal value in any court of law or equity, will require a stamp duty of 5 cts.]	05
Charter Party, or letter, memorandum, or other writing between the captain, owner, or agent of any ship, vessel, or steamer, and any other person, relating to the charter of the same, if the registered tonnage of said ship, vessel, or steamer, does not exceed 150 tons	1 00
Charter Party, exceeding 150 tons, and not exceeding 300 tons	3 00

Ramapo Wheel and Foundry Co.

	STAMP DUTY.
Charter Party, exceeding 300 tons, and not exceeding 600 tons	$5 00
Charter Party, exceeding 600 tons	10 00
Clearance, same as manifest.	
Contract. (See *Agreement.*]	
" Brokers'	10 00
Conveyance, deed, instrument, or writing, whereby lands, tenements, or other realty sold, shall be conveyed, *the actual value of which* does not exceed $500	50
Conveyance, exceeding $500, and not exceeding $1,000	1 00
For every additional $500, or fractional part thereof	50

N. B.—In conveyances of real estate, the law provides that the stamp affixed must answer to the *value* of the estate or interest conveyed.

No stamp is required on any warrant of attorney accompanying a bond or note, when such bond or note has affixed thereto the stamp or stamps denoting the duty required; and whenever any bond or note is secured by mortgage, but one stamp duty is required on such papers, such stamp duty being the highest rate required for such instruments, or either of them. In such case, a note or memorandum of the value or denomination of the stamp affixed should be made upon the margin or in the acknowledgment of the instrument which is not stamped.

Documents made in Foreign Countries.—Any power of attorney, conveyance, or documents of any kind, made or purporting to be made in any foreign country, to be used in the United States, shall pay the same duty as if made or issued in the United States.

Entry of any goods, wares, or merchandise, at any custom-house, either for consumption or warehousing, not exceeding $100 in value	25
Exceeding $100, and not exceeding $500 in value	50
Exceeding $500 in value	1 00
For the withdrawal of any goods or merchandise from bonded warehouse	50
Insurance (marine, inland, and fire), where the consideration paid for the insurance, in cash, premium notes, or both, does not exceed $10	10
From $10 to $50	25
Exceeding $50	50
Insurance (Life), when the amount insured shall not exceed $1,000	25
Insurance (Life), exceeding $1,000, and not exceeding $5,000.	50
" " exceeding $5,000	1 00

	STAMP DUTY.
Lease of Lands or Tenements, where the rent or rental value is $300 or less per annum.....	$ 50
Lease of Lands or Tenements, exceeding $300, for every additional $200, or fraction in excess.....	50

[N. B.—Lease of coal and iron lands, subject to duty under head of "Conveyance." Perpetual lease, subject to stamp under head of "Conveyance"—the stamp duty to be measured by resolving the annual rental into a capital sum.

Clause of guarantee of payment of rent, incorporated or indorsed, 5 cents additional.]

Legal Documents, writ or other original process, commenced in any court of law or equity, stamp duty.....	50
Legal Documents, where the amount claimed in a writ issued by a court not of record is $100 or over	50
Legal Documents, upon every confession of judgment or cognovit, for $100 or over (except in cases where the tax for the writ of a commencement of suit has been paid).....	50
Legal Documents, or other process or appeals from justices' courts, or other courts of inferior jurisdiction, to a court of record.....	50
Legal Documents, warrants of distress, when the amount of rent claimed does not exceed $100.....	25
Legal Documents, when the amount claimed exceeds $100..	50

[N. B.—Each part of an agreement, bill of lading, charter party, contract, or lease, relied on as evidence, either at law or in equity, must be stamped.]

Suits are commenced in many States by other process than writ, viz.: summons, warrant, publication, petition, &c., in which cases these, as the original processes, severally require stamps.

An appeal or instrument by which a suit is transferred from a Justice of the Peace to a superior court is an original process, and subject to stamp duty as such.

Writs of scire facias are subject to stamp duty as original processes.

The jurat of an affidavit, taken before a Justice of the Peace, Notary Public, or other officer duly authorized to take affidavits, is held to be a certificate, and subject to a stamp duty of five cents. Where, however, affidavits are made relative to any petition, motion, or other proceeding in any suit *actually pending* in any court, no stamp duty is chargeable thereon, in consideration of the fifty-cent stamp affixed to the "original process" by which such suit was commenced. The fifty-cent stamp affixed to the "original process" in the commencement of a suit exempts all affidavits made, or certificates issued under it.

Ramapo Wheel and Foundry Co.

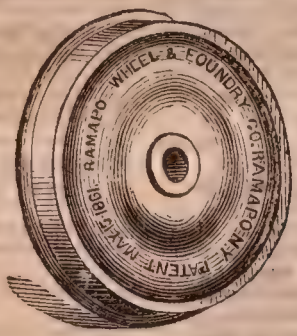
	STAMP DUTY.
Letters of Credit. See "Bills of Exchange, foreign."	
Letters of Administration. See "Probate of Will."	
Manifest for custom-house entry or clearance of the cargo of any ship, vessel, or steamer for a foreign port, if the registered tonnage of such ship, vessel, or steamer does not exceed 300 tons	$1 00
Manifest, exceeding 300 tons, and not exceeding 600 tons	3 00
" exceeding 600 tons	5 00
Matches, friction or lucifer, or other articles made in part of wood, and used for like purposes, in parcels or packages containing 100 matches or less, for each	01
Matches, when in parcels containing more than 100 and not more than 200 matches, for each	02
Matches, for every additional 100 or fraction	01
" segar lights and tapers, double above rates.	
Mortgage of lands, estate, or property, real or personal, heritable or movable, whatsoever, where the same shall be made as a security for the payment of any definite and certain sum of money lent at the time, or previously due and owing, or forborne to be paid, being payable; also, any conveyance of any lands, estate, or property whatsoever, in trust, to be sold, or otherwise converted into money, which shall be intended only as security, and shall be redeemable before the sale or other disposal thereof, either by express stipulation or otherwise; or any personal bond given as security for the payment of any definite or certain sum of money, exceeding $100 and not exceeding $500	50
Exceeding $500, and not exceeding $1,000	1 00
For every additional $500, or fraction in excess of $1,000	50
Pawner's Checks	05
Pension Papers.—Powers of Attorney, and all other papers relating to applications for bounties, arrearages of pay, or pensions, or to receipt therefor	Exempt.
Passage Tickets from the United States to a foreign port, costing not more than $35	$ 50
Costing more than $35, and not exceeding $50	1 00
For every additional $50, or fractional part thereof in excess of $50	1 00
Patent Medicines or Preparations, Bitters, Perfumery, Cosmetics, &c., &c.—On each package retailing at not over 25 cents	01
On each package retailing at from 25 to 50	20
" " " " 50 to 75	03
" " " " 75 to $1	04
" " over $1, each additional 50c. or less	02

	STAMP DUTY.
Power of Attorney to sell or transfer stock, bonds, or scrip, or collect dividends thereon	$ 25
To vote at election of incorporated company	10
To receive or collect rents	25
To sell and convey real estate, or to rent or lease the same	1 00
For any other purpose	50
Photographs, Ambrotypes, Daguerreotypes, or other Sun Pictures, except copies of engravings, or works of art, and those used for the illustration of books, for and upon each picture, where the retail price does not exceed 25 cents	02
Exceeding the retail price of 25 cents, and not exceeding the sum of 50 cents	03
Exceeding the retail price of 50 cents, and not exceeding $1	05
Exceeding the retail price of $1, for every additional dollar or fractional part	05
Probate of Will, or letters of administration, where the value of both real and personal estate does not exceed $2,000	1 00
For every additional $1,000, or fractional part thereof in excess of $2,000	50
Bonds of Executors, Administrators, Trustees, and Guardians, are each subject to stamp duty of	1 00
Letters of Appointment	Exempt.
Certificate of Appointment	$ 05
Protest upon note, bill of exchange, check, draft, &c	25
Promissory Note, or memorandum check, receipt, or other written or printed evidence of an amount of money to be paid on demand, or at a time designated, whether given for *twenty* dollars, or an amount more or *less* than twenty dollars, also judgment notes, are subject to the same stamp duty as "Bills of Exchange, Inland." [A renewal of a Promissory Note subjects it to the same amount of stamp duty as an original note.]	
Quit-Claim Deed should be stamped as "Conveyance," except when given as "release of mortgage," in which case it is exempt.	
Release, discharge, and satisfaction of mortgage	Exempt.
Receipts for the payment of any sum of money, or for the payment of any debt due, exceeding $20, not being for the satisfaction of any mortgage, or judgment, or decree of any court, and a receipt for the delivery of any property, stamp duty	$ 02
Returns, *Gauger's*, for quantity not exceeding 500 galls	10
" " " exceeding 500 galls	25
" *Measurer's*, " not exceeding 1,000 bush	10
" " " exceeding 1,000 bush	25

Ramapo Wheel and Foundry Co.

	STAMP DUTY.
Returns, *Weigher's,* for weight not exceeding 5,000 lbs.....	$ 10
" " " exceeding 5,000 lbs.....	25
Sheriff's Return on writ or other process:..... ...	Exempt.
Trust Deed, made to secure a debt, is to be stamped as a mortgage.	
Trust Deed, conveying estate to uses, should be stamped as "Conveyance." [N. B.—A mortgage or trust deed being duly stamped as a "Mortgage," is not subject to a further stamp duty by virtue of a power of attorney or power of sale contained therein.]	
Warehouse Receipts, for property, goods, wares, or merchandise, not otherwise provided for in any public or private warehouse, when the property or goods so deposited or stored shall not exceed in value $500.....	$ 01
Warehouse Receipts, exceeding in value $500, and not exceeding $1,000.....	20
Warehouse Receipts, exceeding $1,000, for every additional $1,000.....	10
Warehouse Receipts, not otherwise provided for.....	25

RAMAPO WHEEL & FOUNDRY CO.



GEO. COFFING, *President.*
GEO. CHURCH, *Treasurer.*
W. W. SNOW, *Supt., Ramapo, N. Y.*
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RICHMOND IRON WORKS.

S. S. ROBBINS, *President, Salisbury, Ct.*

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RICHMOND IRON WORKS,
West Stockbridge, Mass.

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